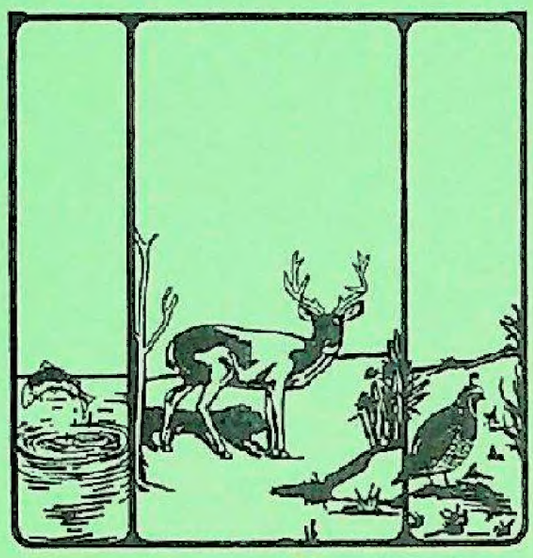
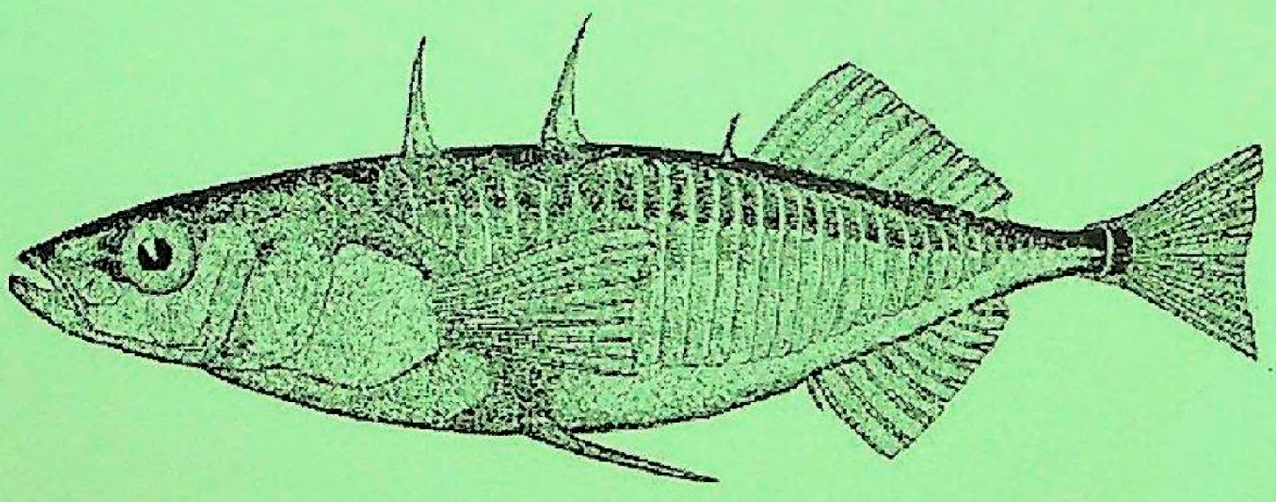
CALIFORNIA FISH and GAME



"CONSERVATION THROUGH EDUCATION"

VOLUME 85 SUMMER 1999 NUMBER 3



California Fish and Game is published quarterly by the California Department of Fish and Game. It is a regional journal devoted primarily to the conservation and understanding of California's flora and fauna, but also accepts papers from the west coast of North America and the northeast Pacific Ocean. If its contents are reproduced elsewhere, the authors and the California Department of Fish and Game would appreciate being acknowledged.

Subscriptions may be obtained at the rate of $15 ($20 for foreign subscribers) per year by placing an order with the Editor, *California Fish and Game*, 4001 North Wilson Way, Stockton, California 95205-2486. Checks or money orders in U.S. dollars should be made out to *California Fish and Game*. Inquiries regarding subscriptions should be directed to the editors. Complimentary subscriptions are granted on an exchange basis.

California Department of Fish and Game employees may request complimentary subscriptions to the journal.

Please direct correspondence to:

David W. Kohlhorst or James J. Orsi
Co-Editors-in-Chief
California Fish and Game
4001 North Wilson Way
Stockton, California 95205-2486
e-mail: dkohlhor@delta.dfg.ca.gov
jorsi@delta.dfg.ca.gov

Individuals interested in obtaining large-print, Braille, or audio versions of this journal should contact the editors.

The California Relay Service telephone number for the hearing-impaired is 1-800-735-2922.

CALIFORNIA FISH AND GAME

VOLUME 85 SUMMER 1999 NUMBER 3

Published Quarterly by

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF FISH AND GAME
--LDA--

STATE OF CALIFORNIA
Gray Davis, *Governor*

THE RESOURCES AGENCY
Mary D. Nichols, *Secretary for Resources*

FISH AND GAME COMMISSION
Richard T. Thieriot, *President*
Michael Chrisman, *Vice President*
Frank D. Boren, *Member*
Douglas B. McGeoghegan, *Member*
Robert R. Treanor, *Executive Director*

DEPARTMENT OF FISH AND GAME
Robert C. Hight, *Director*

CALIFORNIA FISH AND GAME
EDITORIAL STAFF

James J. Orsi and David W. Kohlhorst, *Co-Editors-in-Chief* .....
..... Central Valley Bay-Delta Branch
Donald E. Stevens ..... Central Valley Bay-Delta Branch
Vernon Bleich ..... Eastern Sierra and Inland Deserts Region
Walter Beer, Ralph Carpenter ..... Fisheries Programs Branch
Liam H. Davis ..... Habitat Conservation Planning Branch
Peter Kalvass, David Parker, Marija Vojkovich, Ronald Warner ..... Marine Region
James Harrington ..... Spill Prevention and Response Division
Dan Yparraguirre ..... Wildlife Programs Branch

CONTENTS

ARTICLES

California Wildlife Habitat Relationships System: Effects of County Attributes on Prediction Accuracy for Bird Species .... Barrett A. Garrison, Richard A. Erickson, Michael A. Patten, and Irene C. Timossi 87

Thermal Preference of Female Threespine Sticklebacks under Fed and Food-Deprived Conditions ..... Allison Magee, Christopher A. Myrick, and Joseph J. Cech, Jr. 102

NOTES

Range Extensions of 3 Species of Macrourids from the West Coast of North America ..... Gerald R. Hoff 113

First Eastern Pacific Record of the Goblin Shark, *Mitsukurina owstoni* (Lamniformes: Mitsukurinidae) .... John K. Ugoretz and Jeffrey A. Seigel 118

Northernmost Occurrence of the Slender Tuna, *Allothunnus fallai*, in the Pacific Ocean .... Kurt M. Schaefer and John Childers 121

Predation by Juvenile Hatchery Salmonids on Wild Fall Chinook Salmon Fry in the Lewis River, Washington .... Shane W. Hawkins and Jack M. Tipping 124

First Record of Deepwater Bass, *Serranus aequidens* (Serranidae), from California ..... Daniel J. Pondella, II 130

Northern Range Extension of the White Grunt, *Haemulopsis leuciscus* .... Jorge A. Rosales-Casián and Gorgonio Ruiz-Campos 135

An Animal Track Casting Method Using Dolomite, Sand, and Spray Adhesive ..... Howard O. Clark, Jr. 138

Contents continued on next page

Use of Buried and Non-buried Traps to Sample Desert Rodents
..... Christopher S. Fitzgerald, Paul R. Krausman,
and Michael L. Morrison 140

BOOK REVIEW

Avian Conservation. Research and Management .....
..... Liam H. Davis 144

IN MEMORIAM – Patricia Powell 146

COVER

Threespine Stickleback, *Gasterosteus aculeatus*
Drawing by A.H. Baldwin, from Evermann, B.W. and E. L. Goldsborough. 1907. The fishes of Alaska. Bulletin of the U.S. Bureau of Fisheries 26:219-360.

California Fish and Game 85(3):87-101 1999

CALIFORNIA WILDLIFE HABITAT RELATIONSHIPS SYSTEM: EFFECTS OF COUNTY ATTRIBUTES ON PREDICTION ACCURACY FOR BIRD SPECIES

BARRETT A. GARRISON
California Department of Fish and Game
1416 Ninth Street
Sacramento, California 95814
e-mail: BaGarris@dfg.ca.gov

RICHARD A. ERICKSON
LSA Associates, Incorporated
1 Park Plaza, Suite 500
Irvine, California 92614-5981

MICHAEL A. PATTEN
Department of Biology
University of California
Riverside, California 92521

IRENE C. TIMOSSI[1]
Department of Environmental Science, Policy, and Management
University of California
Berkeley, California 94720

We evaluated how prediction accuracy of bird species occurrences from models in the California Wildlife Habitat Relationships (CWHR) System were affected by county location, size, and number of wildlife habitats. Standardized lists of birds known to occur in 40 counties were compared to CWHR System predictions to calculate 5 measures of prediction accuracy. Multivariate general linear models were used to assess the influence of county attributes on accuracy for 3 bird abundance groups. For all species and common species, total and presence accuracies increased and absence accuracy and omission error decreased as the number of wildlife habitats increased. As county size increased, commission error for all species decreased. For rare species, total and absence accuracies were greater and omission error was lower for inland counties than for coastal counties. Because accuracy was variously affected by different county attributes, depending on species abundance, implications of prediction errors depend on the wildlife management task to which the models are applied. To minimize error, CWHR System queries should be done for areas as large and habitat as diverse as possible.

[1] Deceased.

INTRODUCTION

Site-specific data on species composition of wildlife communities is often needed for conservation, management, and environmental impact assessment. These data can be derived from many sources including inventories, literature reviews, and predictions from wildlife information systems (WIS). These systems have been used by wildlife managers since the advent of widespread computer use some 20 years ago, and at least 20 states (J. Waldon, Fish and Wildlife Information Exchange, personal communication) have some type of operational WIS. Wildlife species composition of an area can be predicted by WIS models, and predictions often substitute for field inventories because inventories are expensive, particularly for large areas (Airola[2] 1988, Edwards et al. 1996). Predictions can also be used as preliminary data to guide inventories. These systems usually have the following types of wildlife information: 1) geographic distribution, 2) habitat relationships, 3) legal status, 4) life history, 5) management actions, 6) seasonality, and 7) taxonomy. Predictions are made by WIS with models that use information on location and habitat.

The California Wildlife Habitat Relationships (CWHR) System is a WIS used for many wildlife management efforts in California because it has detailed information on 675 species of amphibians, reptiles, birds, and mammals that regularly occur in the state. Users include state and federal natural resource and land management agencies, private timber companies, environmental consultants, and universities. Many of California's large-area conservation planning efforts use the CWHR System to predict species composition, habitat suitability, or land use impacts. These efforts include the Gap Analysis Program for California (Scott et al. 1993, Davis et al.[3] 1998), Sierra Nevada Ecosystem Project (Graber 1996), statewide resource assessments (CDFFP 1988), and at least 5 sustained-yield timber management plans for ownerships 200–1,630 km^2 in size (H. Eng, B. Motroni, and B. Valentine, California Department of Forestry and Fire Protection, personal communications).

Users of WIS models expect accurate predictions of species composition for areas and habitats of interest. Hence, system managers and users need to know prediction accuracy, factors affecting accuracy, and implications of errors. Accuracy is rarely evaluated (Marcot et al. 1983, Morrison et al. 1992, Adamus 1995). However, the CWHR System has probably received the most testing of any system in the United States; at least 15 accuracy assessments have been conducted (Garrison[4] 1993).

Usually, WIS models are developed using both published and unpublished information; professional judgement and general knowledge are used when specific information is lacking. Consequently, model accuracy can be highly variable. Accuracy can vary by species and is affected by abundance. For example, model

---

[2] Airola, D.A. 1988. A guide to the California Wildlife Habitat Relationships System. California Department of Fish and Game, Sacramento, California, USA.

[3] Davis, F.W. and 11 others. 1998. The California Gap analysis project report. Department of Geography, University of California, Santa Barbara, California, USA.

[4] Garrison, B.A. 1993. Validation studies of the California Wildlife Habitat Relationships System. Fish and Wildlife Information Exchange Newsletter 2:2-5.

predictions were more accurate for abundant birds than for rare and accidental species (Timothy and Stauffer 1991; Garrison et al.[5], in press). Temporal variation depends on seasonal patterns of the wildlife community and how well these patterns are known (Timothy and Stauffer 1991; Block et al. 1994; Garrison et al.[5], in press). Because of their mobility and migratory habits, birds demonstrate more temporal accuracy variation than amphibians, reptiles, and mammals (Block et al. 1994, Edwards et al. 1996). Prediction accuracy can also vary with size of planning areas (Edwards et al. 1996). Location could also influence accuracy because of the habitats involved and dynamics of local wildlife communities.

Except for the previously cited studies, little effort has been directed at assessing WIS prediction accuracy at different scales, particularly for large areas, many species, and long time periods. This knowledge is important because practical consequences of prediction errors should be understood by WIS system managers and users. For example, over-predicting the number of species can inflate an area's biological importance, whereas omitting the presence of a species with special legal status can misdirect management efforts. Predictions that are less accurate for small areas compared to large areas could bias management efforts. Model predictions are made for areas of varying sizes, locations, and habitat attributes, and users need to know how accuracy varies along those lines so they can have appropriate levels of confidence. To assess the effect of several geographic attributes on model accuracy, we compared CWHR System predictions against standardized lists of bird observations for 40 California counties.

METHODS

Information System Characteristics

The CWHR System consists of matrix-type models where information on the geographic distribution, habitat relationships, legal status, life history, seasonality, and taxonomy of 675 species of regularly occurring amphibians, reptiles, birds, and mammals is stored in database files (Garrison et al.[6] 1996). The CWHR System operates on personal computers using menu-based queries to determine species composition and habitat suitabilities for geographic areas and habitats of interest.

At the time of this study, there were CWHR models for 344 bird species, whereas at least 606 species of birds were known from California (Western Field Ornithologists[7] 1998). The balance of species (n = 262) occur irregularly (i.e., vagrants) and were not modeled because CWHR developers felt they were of less

---

[5] Garrison, B.A., R.A. Erickson, M.A. Patten, and I.C. Timossi. In press. Accuracy of wildlife model predictions for bird species occurrences in California counties. Wildlife Society Bulletin.

[6] Garrison, B.A., K.W. Hunting, and K.J. Sernka. 1996. Training manual for the California Wildlife Habitat Relationships System, Version 6.0. Sixth edition. California Department of Fish and Game, Sacramento, California, USA.

[7] Western Field Ornithologists. 1998. California Bird List of the Western Field Ornithologists. California Bird Records Committee, Camarillo, California, USA.

management interest than regularly occurring species. Bird species models were originally developed some 20 years ago using published and unpublished information as well as professional judgement (Airola[2] 1988). Much of the CWHR Systems's initial bird distribution information, including distribution maps and tabular data, was developed from general references on California birds (McCaskie et al. 1979, Garrett and Dunn 1981) augmented with species-specific information (see Zeiner et al. 1990). Species lists can be generated for seasons defined as winter (December–February), spring (March–May), summer (June–July), and fall (August–November). Updates and improvements to the database are routinely made as errors are identified and new information becomes available.

County Bird Lists

Standardized bird species lists exist for many California counties and offshore islands. These lists were written by ornithologists with considerable local knowledge and were edited for accuracy and consistency. Development, editing, and publication of the lists is sponsored by the Western Field Ornithologists and the Smithsonian Migratory Bird Center. Draft county lists from this project and 1 other existing county list in a similar format were the basis for the 40 lists we analyzed. Regardless of abundance or status, all bird species known to occur in a county are included on the list. The lists cover records accumulated over a minimum of several decades, although some species may not have been observed for many years. Because the CWHR System predicts species occurrences for specific seasons, in contrast to the county lists which employ more flexible seasonal categories based on species- and location-specific movements, the county lists were categorized into the 4 seasons using seasonal patterns from the lists and supplemented with descriptions from Small (1994). Birds were categorized as common (small numbers to many thousands encountered under normal circumstances as regular occurrences) or rare (exceedingly few to few individuals encountered as regular, irregular, casual, or accidental occurrences) based on their statewide abundance following definitions modified from DeSante and Pyle (1986). The county lists lacked information about habitat relationships.

Accuracy Testing

A total of 160 county-by-season lists (40 counties by 4 seasons) were compared against lists of bird species predicted for the same combinations using the MS-DOS® edition of CWHR (Version 5.3) available during the study. The companion WINDOWS® edition of CWHR (Version 6.0) has the same data as Version 5.3. Statistical tests were done using accuracy measures averaged among the 4 seasons to 1) alleviate potential inconsistencies between seasonal definitions used by the CWHR System and the county lists and 2) minimize possible effects of seasonal differences in accuracy which were analyzed elsewhere (Garrison et al.[5], in press).

The county lists represent an extensive set of independent, standardized data that could be used to evaluate CWHR prediction accuracy patterns involving many taxa and large geographic areas. Our purpose was to evaluate how prediction accuracy

is affected by county attributes such as location, size, and habitat diversity. We did not explicitly test CWHR predictions for birds in California counties because published county lists are preferable to WIS predictions when county-specific bird lists are available. The county lists did, however, provide data for 40 locations that differed in many area attributes that might affect accuracy. Counties are independent geographic units because of their large size, habitat diversity, and species differences (Appendix A) and the tremendous geographic variation in California's landscape.

The county lists are independent from the CWHR data because the lists were not available when locational data in the CWHR System were originally developed. Locational data were developed using older literature that covered geographic areas larger than counties, including McCaskie et al. (1979) for northern California and Garrett and Dunn (1981) for southern California. County lists used in this study were developed approximately 15 years later than these references. Because California's bird communities are highly dynamic, particularly for less common species, numerous changes have occurred in the distribution and abundance of the state's avifauna in the 20 years since the CWHR data were originally developed (see Small 1994).

Only the locational component of the CWHR System was used because it predicts presence or absence of a species for a county by season combination. A location-only CWHR prediction for presence assumes that suitable habitat is present and occupied. The habitat-relationships models were not used to refine the predicted species lists because the county lists had no habitat affinities associated with individual species. Also, the CWHR System's habitat models assume habitat use and suitability throughout the species' and habitat's statewide distribution, so incorporating the habitat models would have required us to make assumptions about county-specific habitat relationships for which the lists lacked data.

The validity of using the CWHR System to generate location-only species lists should improve as area size and number of habitats increase. The assumption that some habitat used by a species occurs in an area is more likely to be met for larger areas, and the likelihood of a species actually occurring increases with area size and habitat diversity, as does its prediction by CWHR. We felt that the habitat assumption was met because the counties had large areas (1,156–52,071 km^2) and many habitats (20–48) (Appendix A). The effect, therefore, of excluding habitats from the queries was negligible, especially given the assumptions we would have had to make regarding county-specific habitat use patterns.

We used a 2x2 error matrix to calculate accuracy measures for each county by season list by comparing species from each county bird list against species from the CWHR list. Error matrices are commonly used to assess accuracy from remote sensing image classification (Congalton 1991) and wildlife model predictions (Morrison et al. 1992). Overall accuracy (%) (Marcot et al. 1983, Congalton 1991) was calculated using correct predictions for presence (predicted species observed in county [P]) and absence (species absent from both CWHR and county lists [A]). Levels (%) of commission error (species predicted but not observed [C]) and omission error (species observed but not predicted [O]) were also calculated. Accuracy measures (%) were

calculated as follows:

Overall accuracy = [(P + A)/(P + A + C + O)]*100
Presence accuracy = [P/(P + A + C + O)]*100
Absence accuracy = [A/(P + A + C + O)]*100
Commission error = [C/(P + A + C + O)]*100
Omission error = [O/(P + A + C + O)]*100

The total number of bird species for the county was the maximum number of species with CWHR models that were or were not detected among all seasons. Species lists by season for the county list and CWHR were combined to determine P, C, and O, while A = [(P + C + O) - total number of species for the county]. Therefore, the sum of P + A + C + O was the same for each season within a county because A increased or decreased depending on P, C, and O.

There are many formulas suitable to determine prediction accuracy from error matrices (Marcot et al. 1983, Congalton 1991, Morrison et al. 1992, Adamus 1995). We chose to calculate the accuracy measures using the matrix total (Marcot et al. 1983, Congalton 1991) as the denominator because we wanted the measures to be scaled equally, sum to 100%, and to allow easier quantitative and qualitative comparisons among the 5 measures and 40 counties.

Accuracy measures were calculated for different species groups, including 1) common species, 2) rare species, and 3) all species. The 2x2 error matrices were symmetrical (equal total number of species) for each season within a county. To more precisely and unambiguously determine accuracy for species in CWHR, accuracy was calculated for those species on the county lists with CWHR models.

Accuracy can be influenced by large-scale landscape features, so accuracy was compared between counties occurring on the coast, including San Francisco Bay (coastal counties, n = 13), and inland counties (n = 27). County size (km^2) was determined from a statewide county location map developed in a geographic information system (GIS). The number of habitats per county was determined from several sources, including statewide vegetation maps from a GIS and tabular data developed from habitat inventories from California Department of Fish and Game county wildlife biologists and the CWHR Program. Habitats were classified according to the CWHR habitat classification system (Mayer and Laudenslayer 1988). Because of the range in number of species (231–311) (Appendix A) on the county lists, accuracies were calculated as percentages to equalize measures among counties.

We used SYSTAT's multivariate general linear models (SPSS, Inc. 1998) to analyze the effects of county attributes on prediction accuracy. Models were developed for 1) common species, 2) rare species, and 3) all species. Predictor variables were continuous (county size and habitat number) and categorical (location). Accuracy values were averages among the 4 seasons for the 5 measures. Forward selection was used to select the best linear model and predictor variables were sequentially entered into the model as single variables, groups of single variables, 2-way interactions, and finally as combinations of single variables and 2-way interactions until the model with the best fit (greatest F and P values) was determined. Predictor variables were removed if multivariate Wilks' lambda F-tests were insignificant ($P > 0.05$)

until the model contained variables that had significant (P <0.05) Wilks' lambda F-tests. To normalize the data, accuracy levels (as proportions, not percentages) were arcsine transformed and county size was $\log_{10}$ transformed (Zar 1997).

RESULTS

For all species, multivariate tests indicated that prediction accuracy varied by county size (P = 0.013) and number of habitats (P = 0.008) (Table 1). Univariate tests for all species indicated that, as habitat number increased, total accuracy (P = 0.05) and presence accuracy (P = 0.003) increased, and absence accuracy (P = 0.037) and omission error (P = 0.043) decreased (Table 1, Fig. 1). Also for all species, commission error decreased as county size increased (P = 0.017) (Table 1, Fig. 1). For common species, accuracy was affected by number of habitats (P = 0.000) (Table 1). All accuracy measures for common species except commission error (P = 0.632) varied with number of habitats (Table 1). For common species, total accuracy (P = 0.033) and presence accuracy (P = 0.000) increased, while absence accuracy (P = 0.001) and omission error (P = 0.003) decreased as number of habitats increased (Fig. 2). Prediction accuracy for rare species was affected by county location (P = 0.022), and 3 accuracy measures varied by location (Table 1). For rare species, total accuracy was greater (P = 0.034) for inland counties (mean = 69.7%, SE = 1.4%) than coastal counties (mean = 65.1%, SE = 1.5%), and absence accuracy was greater (P = 0.003) for inland counties (mean = 42.4%, SE = 1.2%) than coastal counties (mean = 35.3%, SE = 1.7%). For rare species, omission error was greater (P = 0.013) for coastal counties (mean = 33.2%, SE = 1.4%) than inland counties (mean = 27.4%, SE = 1.6%).

DISCUSSION

We found that prediction accuracy of the CWHR System for bird species occurrence in California counties was influenced by a county's location, size, and number of wildlife habitats. These results demonstrate that CWHR model accuracy is affected by geographic factors. The most pronounced effect on prediction accuracy was caused by the number of habitats in a county because accuracy increased as the number of habitats increased for all species and common species. Location influenced prediction accuracy for rare species, as inland counties had greater prediction accuracy than coastal counties. For all species, commission error was the only measure affected by county size in univariate tests, indicating a comparatively weak effect of county size on prediction accuracy.

Although county size and number of habitats are positively associated (r = 0.483, n = 40, P = 0.003), our results indicate that habitat number has a greater role in prediction accuracy than area. This might have been expected as the number of habitats in an area ultimately determines the total number of species occurring there (Morrison et al. 1992).

For all species and common species, presence accuracy increased and absence accuracy decreased as habitat number increased, indicating that CWHR models more accurately predicted species presence and less accurately predicted absence for

Table 1. Univariate and multivariate general linear model analyses of the effects of county attributes on prediction accuracy of the California Wildlife Habitat Relationships System for bird species composition of 40 counties in California. Models are those with significant (P <0.05) multivariate tests using forward selection.

	Univariate tests											Multivariate tests		
	Accuracy							Error						
	Total			Presence		Absence		Commission		Omission		Wilks' Lambda		
Species group	df	F	P	F	P	F	P	F	P	F	P	df	F	P
All species														
County size	1,37	0.54	0.469	0.01	0.914	0.03	0.854	6.21	0.017	0.31	0.582	5,33	3.47	0.013
Number of habitats	1,37	4.12	0.050	10.18	0.003	4.67	0.037	0.02	0.896	4.38	0.043	5,33	3.76	0.008
Common species														
Number of habitats	1,38	4.92	0.033	19.37	0.000	14.70	0.001	0.23	0.632	10.43	0.003	5,34	6.85	0.000
Rare species														
County location	1,38	4.82	0.034	0.78	0.384	9.88	0.003	1.28	0.266	6.76	0.013	5,34	3.05	0.022

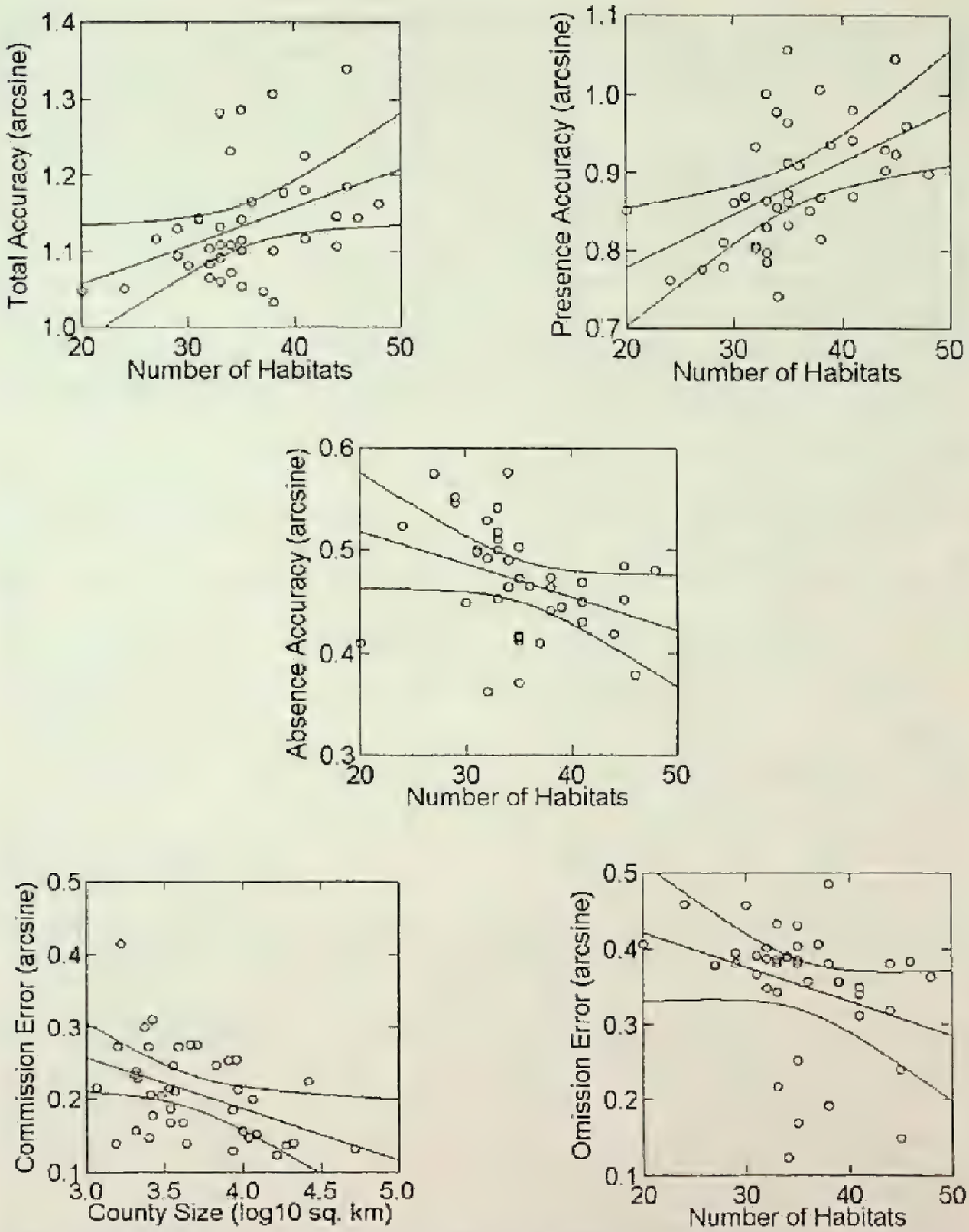


Figure 1. Significant relationships (P <0.05) between prediction accuracy (arcsine transformed) of the California Wildlife Habitat Relationships System for all bird species in a county and number of habitats and county size ($\log_{10}$ transformed). Lines are linear regressions and 95% confidence intervals.

counties with more habitats. This result illustrates the compensatory relationship between presence and absence accuracy using a 2x2 error matrix. The highest possible levels of presence accuracy are desired by CWHR System users because management

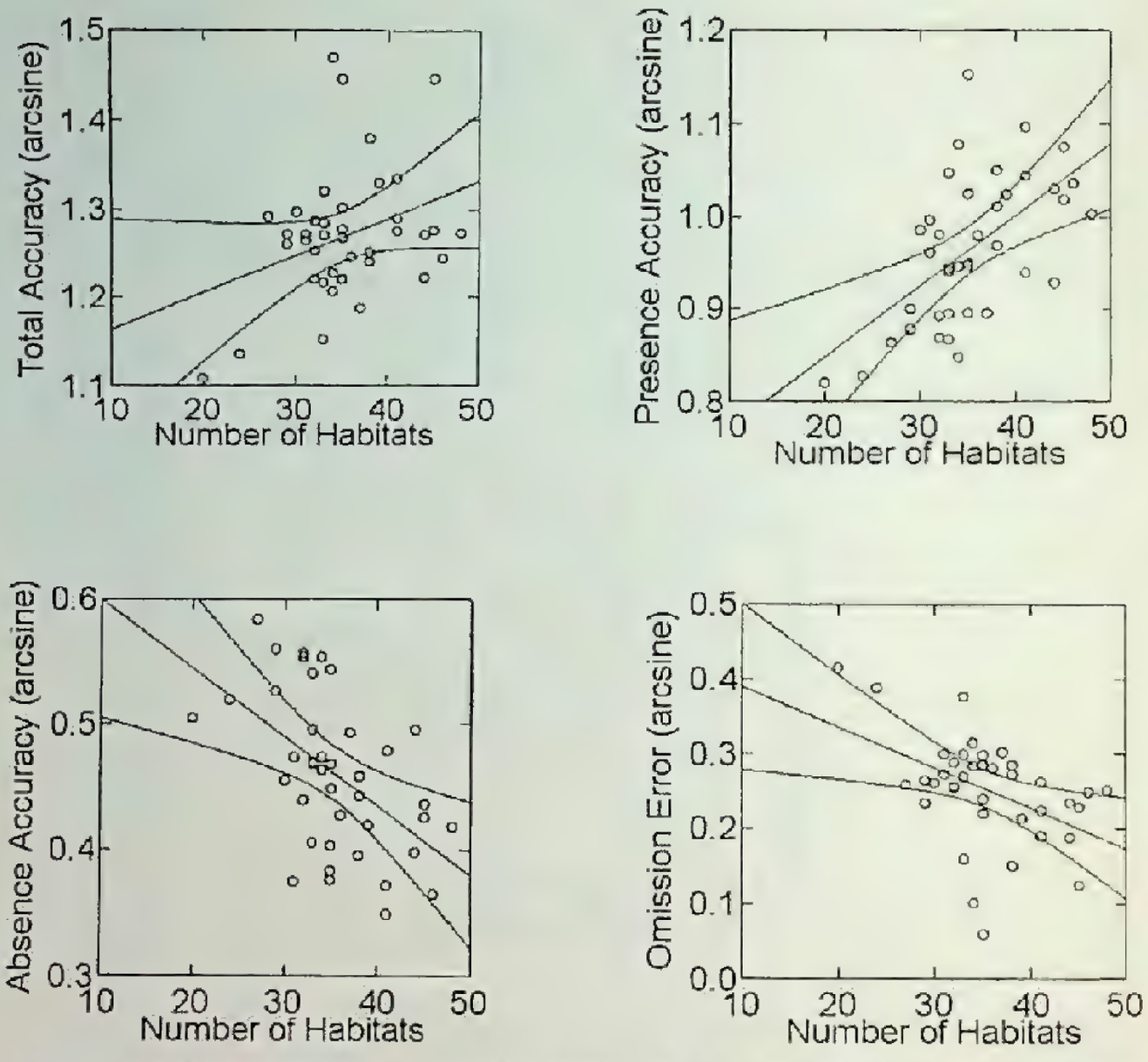


Figure 2. Significant relationships (P <0.05) between prediction accuracy (arcsine transformed) of the California Wildlife Habitat Relationships System for common bird species and number of habitats in a county. Lines are linear regressions and 95% confidence intervals.

actions are usually directed at species present in an area. Commission and omission errors are measures of over-predicting and under-predicting, respectively, the number of species for an area. Commission error declined with increasing county size, indicating there were fewer over-prediction errors for larger counties. Omission error declined as habitat number increased, but was unaffected by county size, indicating that omissions are more influenced by habitat diversity than by size.

Location only influenced accuracy for rare species. Coastal counties have more rare species than inland counties (Small 1994) and models are less accurate for rare species (Garrison et al.[5], in press), so prediction errors are more likely for coastal counties. The influence of the coast and ocean in attracting rare species to coastal counties (Small 1994) is likely the primary reason for reduced accuracy. Size and number of habitats probably has little effect on prediction accuracy for rare species because: 1) model error for these species varies throughout California; and 2) there are relatively few rare species, so it is more difficult to detect statistical relationships

with those 2 geographic attributes. Furthermore, coastal counties are smaller and more similar in size (mean = 4,388 km^2, CV = 73.3%) than inland counties (mean = 9,084 km^2, CV = 119.2%), and they have less variation in habitat number (CV = 7.0%) than inland counties (CV = 19.7%).

Several studies of CWHR accuracy for birds have reported accuracy levels similar to ours, except for greater levels of commission errors (Hejl and Verner 1988, Avery and Van Riper 1990, Purcell et al. 1992, Block et al. 1994). Greater commission errors for these studies should be expected because they were conducted in areas smaller than the counties used in our analysis and area size and commission error are inversely related. Furthermore, these studies, while valuable in identifying errors in CWHR models, were conducted using data collected from shorter time frames than our study. Most tests of CWHR accuracy have involved areas <100-200 ha with 2–4 habitat types and 1–3 years of field effort (Garrison[4] 1993). We tested model accuracy for 344 bird species and 40 counties from 1,156–52,071 km^2 in size, the largest WIS accuracy assessment attempted to date. Thus, we looked at accuracy patterns that can be affected by factors more consistent with CWHR applications for larger areas and more habitats. The county lists typically resulted from decades of field observations by dozens of observers over large areas and many habitats, thereby accounting for most of the species predicted by CWHR models. Therefore, omission errors should increase and commission errors should decrease with large-area and long-term field efforts because of the high likelihood of encountering all species present in an area.

Several authors have demonstrated that model accuracy increases as the time and area scales of the study increase (Timothy and Stauffer 1991, Block et al. 1994, Edwards et al. 1996). Edwards et al. (1996), for example, found that accuracy increased as the size of 8 Utah National Parks increased, but they did not assess the differential effect of habitat diversity. Area size and habitat diversity are related, however, as larger areas support more habitats (see Scott et al. 1993, Edwards et al. 1996). Increasing the number of habitats can increase accuracy if predicted species lists are composite lists without regard to habitat affinities or there is differential accuracy in the habitat models themselves. We tested the locational component of the CWHR System and not the effect of habitat model predictions on model accuracy. We did, however, assess the overall effect of habitat diversity in an area by demonstrating that accuracy increased as the number of habitats increased.

Given our results, applying WIS to conservation efforts involving small areas, few habitats, and short time frames, particularly those involving substantial numbers of rare species, should be done cautiously. Queries of small areas should use all components of the CWHR model, including location, habitat type, and habitat elements. Accuracy was greatest for areas with many habitats (typically larger counties), so conservation efforts using the CWHR System for large areas with many habitats involving most members of the wildlife community seem appropriate given the observed accuracy patterns. Users are cautioned about applying the CWHR System to projects involving relatively small geographic areas and few habitats (Airola[3] 1988, Mayer and Laudenslayer 1988, Garrison 1994, Garrison et al.[6] 1996).

Furthermore, predictions from WIS typically produce commission errors due to their inherent model structure, underlying assumptions, and small areas for which predictions are often generated. Our results showed that commission error increased with smaller areas, while omission error increased as habitat diversity decreased. The positive relationship between area size and habitat diversity means that predictions from large areas with multiple habitats should reduce both errors.

The differing effects of 3 county attributes (location, habitat diversity, and size) indicate that model accuracy can be influenced by factors that were not explicitly considered when the statewide models were designed. The CWHR System and most other WIS are actively managed so that they are modified and improved as errors are identified and new information becomes available, including results from this accuracy assessment. For example, since 1991 some 30,000 changes have been made to the CWHR System based largely on accuracy assessments, but more accuracy testing is needed to continually rectify model errors and improve model functionality. Apart from possibly developing separate models for different geographic attributes, CWHR users are encouraged to make queries for as large an area with as many habitats as possible.

ACKNOWLEDGMENTS

This paper is dedicated to the memory of Irene Timossi and her significant contributions to the CWHR System and our knowledge of California's wildlife. We sincerely appreciate the individuals who prepared the county lists, including A. Barron, E. Beedy, W. Bousman, K. Campbell, B. Deuel, T. Edell, R. Ekstrom, A. England, R. Erickson, H. Green, W. Grummer, R. Hamilton, S. Harris, J. and T. Heindel, M. Heindel, J. Hornstein, L. Jensen, R. Keiffer, W. Laudenslayer, Jr., R. Leong, G. Lester, T. Manolis, C. Marantz, P. Metropulos, B. Parmeter, M. Patten, R. Richmond, M. Rippey, M. Robbins, D. Roberson, P. Sands, J. Snowden, R. Stallcup, J. Sterling, B. Stoval, E. Strauss, D. Suddjian, W. Sumner, K. Van Vuren, J. White, B. Williams, D. Willick, D. Yee, and B. Yutzy. The Federal Aid in Wildlife Restoration Act provided partial support for the staff time of B. Garrison to write this paper. G. He provided advice on statistical analyses. G. He, J. Howell, K. Hunting, D. Kohlhorst, J. Orsi, J. Waldon, and an anonymous reviewer deserve special thanks for their insightful and helpful reviews of the paper.

LITERATURE CITED

Adamus, P.R. 1995. Validating a habitat evaluation method for predicted avian richness. Wildlife Society Bulletin 23:743-749.

Avery, M.L. and C. Van Riper III. 1990. Evaluation of wildlife-habitat relationships database for predicting bird community composition of central California chaparral and blue oak woodlands. California Fish and Game 76:103-117.

Block, W.M., M.L. Morrison, J. Verner, and P.N. Manley. 1994. Assessing wildlife-habitat-relationships models: A case study with California oak woodlands. Wildlife Society Bulletin 22:549-561.

CDFFP. 1988. California's forests and rangelands: Growing conflict over changing uses. California Department of Forestry and Fire Protection, Forest and Rangeland Resources Assessment Program, Sacramento, California, USA.

Congalton, R.G. 1991. A review of assessing the accuracy of classifications of remotely sensed data. Remote Sensing of Environment 37:35-46.

DeSante, D.F. and P. Pyle. 1986. Distributional checklist of North American birds, volume 1: United States and Canada. Artemisia Press, Lee Vining, California, USA.

Edwards, T.C., Jr., E.T. Deshler, D. Foster, and G.G. Moisen. 1996. Adequacy of wildlife habitat relation models for estimating spatial distribution of terrestrial vertebrates. Conservation Biology 10:263-270.

Garrett, K. and J. Dunn. 1981. Birds of southern California: Status and distribution. Los Angeles Audubon Society, Los Angeles, California, USA.

Garrison, B.A. 1994. Determining the biological significance of changes in predicted habitat values from the California Wildlife Habitat Relationships System. California Fish and Game 80:150-160.

Graber, D. M. 1996. Status of terrestrial vertebrates. Pages 709-734 *in:* Sierra Nevada Ecosystem Project: Final report to Congress, volume II. Wildland Resources Center Report No. 37.

Hejl, S.J. and J. Verner. 1988. Evaluating avian-habitat relationships in red fir forests of the Sierra Nevada. Western Section of the Wildlife Society Transactions 24:121-134.

Marcot, B.G., M.G. Raphael, and K.H. Berry. 1983. Monitoring wildlife habitat and validation of wildlife-habitat relationships models. North American Wildlife and Natural Resources Conference Transactions 48:315-329.

Mayer, K.E. and W.F. Laudenslayer, Jr., editors. 1988. A guide to wildlife habitats of California. California Department of Forestry and Fire Protection, Sacramento, California, USA.

McCaskie, G., P. De Benedictis, R. Erickson, and J. Morlan. 1979. Birds of northern California, an annotated field list. Second edition. Golden Gate Audubon Society, Berkeley, California, USA.

Morrison, M.L., B.G. Marcot, and R.W. Mannan. 1992. Wildlife-habitat relationships. University of Wisconsin Press, Madison, Wisconsin, USA.

Purcell, K.L., S.J. Hejl, and T.A. Larson. 1992. Evaluating avian-habitat relationships models in mixed-conifer forests of the central Sierra Nevada. Western Section of the Wildlife Society Transactions 28:120-136.

Scott, J.M. and 11 others. 1993. Gap analysis: A geographic approach to protection of biological diversity. Wildlife Monographs 123:1-41.

Small, A. 1994. California birds: Their status and distribution. Ibis Publishing Co., Vista, California, USA.

SPSS, Inc. 1998. SYSTAT® 8.0 for Windows®: Statistics. Chicago, Illinois, USA.

Timothy, K.G. and D.F. Stauffer. 1991. Reliability of selected avifauna information in a computerized information system. Wildlife Society Bulletin 19:80-88.

Zar, J. 1997. Biostatistics. Second edition. McGraw-Hill Publishers, New York.

Zeiner, D.C., W.F. Laudenslayer, Jr., K.E. Mayer, and M. White, editors. 1990. California's wildlife, volume II, birds. California Department of Fish and Game, Sacramento, California, USA.

Received: 27 February 1998
Accepted: 2 October 1999

Appendix A. Geographic attributes and prediction accuracy levels for all bird species (mean for 4 seasons) from 40 California counties used to assess the effects of county attributes on prediction accuracy of the California Wildlife Habitat Relationships System.

County	Size (km²)	Location[a]	Number of habitats	Prediction accuracy measures (mean ± SE)					Number of species on county list[b]
				Total	Presence	Absence	Omission	Commission	
Alameda	2,123	c	33	79.1 ± 5.3	54.4 ± 4.1	24.7 ± 3.8	15.8 ± 5.3	5.2 ± 0.4	292
Butte	4,343	i	39	84.1 ± 5.1	64.9 ± 0.8	19.2 ± 4.9	13.9 ± 5.5	2.0 ± 0.4	276
Colusa	2,994	i	32	78.8 ± 5.7	64.5 ± 1.1	14.2 ± 5.6	17.0 ± 6.4	4.3 ± 1.1	246
Contra Costa	2,084	c	35	78.4 ± 6.2	54.6 ± 4.5	23.8 ± 5.1	16.0 ± 6.4	5.7 ± 0.9	282
Del Norte	2,631	c	34	88.9 ± 0.5	68.5 ± 4.5	20.8 ± 4.1	1.7 ± 0.6	9.4 ± 1.0	280
El Dorado	4,636	i	44	79.4 ± 4.8	61.6 ± 2.9	17.8 ± 6.0	12.7 ± 6.8	7.9 ± 2.2	257
Glenn	3,437	i	35	81.8 ± 4.8	67.2 ± 1.1	14.4 ± 5.0	15.3 ± 5.3	2.9 ± 0.7	252
Humboldt	9,282	c	35	91.9 ± 1.5	75.2 ± 4.7	16.7 ± 4.1	3.2 ± 1.2	4.9 ± 1.9	301
Imperial	11,608	i	24	73.9 ± 8.2	47.7 ± 4.0	26.3 ± 8.4	22.0 ± 9.1	4.1 ± 1.1	298
Inyo	26,496	i	33	75.1 ± 7.4	50.0 ± 4.2	25.1 ± 7.9	19.8 ± 8.5	5.5 ± 1.3	300
Kern	21,114	i	48	83.2 ± 5.1	61.2 ± 0.8	22.0 ± 5.2	14.8 ± 6.0	2.3 ± 1.1	299
Lake	3,447	i	31	81.9 ± 4.8	58.5 ± 1.3	23.7 ± 5.4	14.4 ± 5.5	3.7 ± 1.3	255
Lassen	12,220	i	38	92.6 ± 2.7	70.9 ± 5.8	21.7 ± 6.6	4.9 ± 3.0	2.5 ± 0.8	264
Marin	1,534	c	31	81.6 ± 6.0	58.1 ± 4.2	23.5 ± 5.9	16.3 ± 6.5	2.1 ± 0.6	302
Mendocino	9,100	c	38	78.8 ± 5.1	58.1 ± 2.3	20.6 ± 5.0	14.9 ± 5.0	6.4 ± 0.6	287
Merced	5,104	i	32	75.5 ± 6.9	52.1 ± 4.8	23.4 ± 7.2	16.9 ± 8.0	7.6 ± 1.9	252
Modoc	10,887	i	33	91.0 ± 3.6	70.5 ± 5.4	20.5 ± 7.3	6.7 ± 4.2	2.3 ± 0.6	261
Mono	8,114	i	34	76.1 ± 7.0	45.6 ± 5.8	30.5 ± 8.7	17.3 ± 8.4	6.5 ± 1.6	287
Monterey	8,580	c	35	79.7 ± 5.3	62.2 ± 3.4	17.5 ± 5.3	18.6 ± 5.7	1.7 ± 0.4	303
Napa	2,047	i	33	81.2 ± 4.9	57.7 ± 2.9	23.5 ± 5.0	13.4 ± 5.9	5.5 ± 1.1	260
Nevada	2,522	i	41	84.7 ± 4.6	65.3 ± 2.6	19.3 ± 4.2	13.0 ± 5.2	2.3 ± 0.7	261
Orange	2,070	c	30	77.0 ± 6.3	57.3 ± 5.8	19.6 ± 5.7	20.6 ± 6.3	2.5 ± 0.4	294
Placer	3,885	i	45	85.5 ± 2.6	63.7 ± 0.9	21.8 ± 2.9	7.1 ± 3.8	7.4 ± 1.3	269
Plumas	6,773	i	41	79.7 ± 6.4	58.1 ± 6.3	21.6 ± 7.6	14.1 ± 7.8	6.3 ± 1.5	256
Riverside	18,908	i	46	82.0 ± 5.0	67.1 ± 0.8	14.9 ± 5.1	15.7 ± 6.0	2.3 ± 1.1	311
Sacramento	2,573	i	27	79.3 ± 7.2	49.0 ± 4.2	30.2 ± 7.3	16.5 ± 7.9	4.3 ± 0.8	263

Appendix A. Continued.

County	Size (km²)	Location[a]	Number of habitats	Prediction accuracy measures (mean ± SE)					Number of species on county list[b]
				Total	Presence	Absence	Omission	Commission	
San Benito	3,599	i	33	78.1 ± 4.8	51.2 ± 2.7	26.9 ± 4.8	15.5 ± 6.3	6.2 ± 1.6	249
San Bernardino	52,071	i	44	81.8 ± 5.7	64.2 ± 1.8	17.7 ± 5.6	15.8 ± 6.8	2.3 ± 1.3	303
San Joaquin	3,690	i	29	77.7 ± 7.1	49.3 ± 4.4	28.4 ± 7.8	17.6 ± 8.4	4.5 ± 1.4	267
San Luis Obispo	8,599	c	38	71.9 ± 9.7	53.2 ± 5.9	19.0 ± 5.4	24.6 ± 10.3	3.5 ± 0.9	305
Santa Clara	3,383	c	34	79.5 ± 4.5	56.9 ± 2.6	22.6 ± 4.4	16.0 ± 5.5	4.7 ± 1.0	289
Santa Cruz	1,156	c	35	78.9 ± 5.1	57.5 ± 4.1	21.3 ± 5.4	16.8 ± 5.6	4.6 ± 0.6	292
Shasta	9,963	i	45	94.3 ± 2.0	74.4 ± 4.0	19.8 ± 5.3	3.2 ± 2.3	2.5 ± 0.3	262
Sierra	2,492	i	37	74.2 ± 6.7	56.3 ± 8.4	18.0 ± 8.7	18.0 ± 8.6	7.8 ± 2.5	231
Siskiyou	16,451	i	41	87.4 ± 4.5	68.8 ± 4.5	18.7 ± 6.4	11.0 ± 4.8	1.6 ± 0.6	276
Solano	2,356	c	32	77.6 ± 4.7	51.5 ± 4.2	25.8 ± 4.9	13.5 ± 6.0	8.9 ± 1.7	271
Sonoma	4,149	c	36	83.0 ± 6.0	62.1 ± 4.4	20.8 ± 5.5	14.2 ± 6.1	2.9 ± 0.6	289
Sutter	1,576	i	20	74.2 ± 6.7	56.3 ± 8.4	18.0 ± 8.7	18.0 ± 8.6	7.8 ± 2.5	231
Yolo	2,646	i	29	80.3 ± 6.9	52.2 ± 4.0	27.8 ± 7.3	16.4 ± 7.6	3.3 ± 1.1	265
Yuba	1,668	i	35	75.4 ± 2.4	58.6 ± 1.9	16.8 ± 3.4	8.2 ± 4.2	16.4 ± 2.4	239

[a] Location: c = coastal; i = interior.

[b] Number of species with CWHR models; species without CWHR models were not included.

California Fish and Game 85(3):102-112 1999

THERMAL PREFERENCE OF FEMALE THREESPINE STICKLEBACKS UNDER FED AND FOOD-DEPRIVED CONDITIONS

ALLISON MAGEE, CHRISTOPHER A. MYRICK, and JOSEPH J. CECH, JR.
Department of Wildlife, Fish, and Conservation Biology
University of California, Davis
Davis, California 95616-8751
e-mail: jjcech@ucdavis.edu

Preferred temperatures of food-deprived (>24 hours post feeding) and fed (<2 hours post feeding) female marine threespine sticklebacks, *Gasterosteus aculeatus*, from the Bodega Harbor, California, population were determined using a laboratory, horizontal temperature gradient apparatus. Food-deprived fish preferred significantly cooler temperatures (mean = 15.9°C, final = 15.8°C) than fed fish (mean = 20.1°C, final = 19.0°C), with larger specimens preferring lower temperatures than smaller specimens. Food-deprived fish would probably benefit from this behavior by conserving energy (approximately 17% decrease in metabolic requirements at the lower temperature), whereas fed fish would probably benefit by decreasing gut transit times, facilitating energy acquisition.

INTRODUCTION

Temperature is an important abiotic variable affecting fish behavior, distribution, reproduction, energy budgets, and other physiological processes (Cherry et al. 1977, Cech et al. 1990, Wood and McDonald 1997). Some fish function more efficiently within a narrow temperature range (Hainsworth 1981, Hopkins and Cech 1994), though this "optimal" range may vary with ontogeny, size, food availability, and other factors. With the exception of those in thermally homogenous environments (e.g., the deep sea; Randall and Farrell 1997), many fishes are subject to variable temperatures. Therefore, it is important to either regulate internal body temperature to remain within the optimal range or undergo physiological or biochemical changes that optimize function under different environmental conditions (Hochachka 1991, Somero 1995).

With the exception of some tunas, billfish, and pelagic sharks (Dewar et al. 1994), fish are true ectotherms, regulating body temperatures by movements between microhabitats (Reynolds and Casterlin 1978, Brio 1998), a process known as behavioral thermoregulation. If a thermal gradient is available, fish may behaviorally thermoregulate by moving to a preferred temperature area (termed "thermal preference" by Beitinger and Fitzpatrick [1979]). Because the thermal preference of a fish is dependent upon its acclimation temperature (Cherry et al. 1977, Jobling 1981), previous workers have defined the "final temperature preferendum" as the

temperature at which fish of a given species will eventually congregate if exposed to a temperature gradient for an extended time period (Roed 1979, Jobling 1981).

Few studies have examined relationships between thermal preference and feeding rates, although food availability and environmental temperatures have profound effects on metabolic processes and related behaviors. If adequate food is available, fish feed (acquire energy) in proportion to the rates of their metabolic processes (e.g., body maintenance, growth, activity, reproduction) (Adams and Breck 1990, Jobling 1994). With food deprivation, these physiological processes and related behaviors are influenced (Blasco et al. 1992). Thermal preference is a behavior that is influenced by food deprivation, but the response varies with species (Javaid and Anderson 1967, Wurtsbaugh and Davis 1977, Ehrlich et al. 1979). Because metabolic processes are directly related to temperature, it would be an adaptive advantage for fish to choose a cooler temperature when their food supply is limited (Ehrlich et al. 1979, Lemons and Crawshaw 1985, Brandt 1993). Cooler temperatures would lower overall energy requirements and prolong homeostasis and survival. Conversely, when food is abundant, fishes may select warmer temperatures to increase the speed of metabolic processes (Nevermann and Wurtsbaugh 1994).

The threespine stickleback, *Gasterosteus aculeatus*, is a small euryhaline teleost with a circumpolar distribution in north-temperate latitudes (Lee et al. 1980). It inhabits shallow water habitats in both fresh and salt water, generally in close proximity to heavy vegetation, especially in areas where there is a high predation risk (Moyle 1976, Moyle et al. 1982). It has a wide salinity tolerance (Garside et al. 1977), can tolerate a wide range of water temperatures (Jordon and Garside 1972) (but generally prefers temperatures <24°C, Moyle 1976), and shows differences in growth and swimming performance that are genetically related to life history strategy (Taylor 1986, Snyder 1991). The threespine stickleback has complex breeding behavior, parental care, and foraging-related social interactions (see reviews by Wooton 1976, 1984).

Although threespine stickleback behavior has been extensively studied, fewer studies have been done on the physiological effects of temperature. Studies on temperature and oxygen tolerance limits (Feldmeth and Baskin 1977), temperature effects on egg production (Boule and Fitzgerald 1989), and temperature-related metabolic capacities and growth (Guderley et al. 1994) have been conducted. Using vertical thermal gradients, Garside et al. (1977) found that threespine stickleback preferred warmer temperatures when acclimated to sea water conditions than when acclimated to fresh water. Roed (1979) determined that they preferred warmer temperatures at higher acclimation temperatures. To our knowledge, no one has investigated the temperature preference of food-deprived threespine sticklebacks. Given the temperature-dependence of metabolic and food consumption rates (reviewed by Fry 1971, Brett and Groves 1979), such information would provide additional insight to the habits of this widely distributed fish. Based on Ehrlich et al.'s (1979) studies on California littoral fishes, we hypothesized that fed female threespine stickleback would have higher thermal preferences than food-deprived ones. Therefore, the objective of our study was to measure the effects of food deprivation on the thermal preference of marine threespine sticklebacks.

METHODS

Threespine sticklebacks were seined from shallow (<1 m) intertidal mudflats and eel grass, *Zostera* sp., beds (salinity: 33‰) in Bodega Harbor, Bodega Bay, California, on 20 June 1996. Fish were visually sexed by examining them for obvious red spots on the body and only non-gravid females (those lacking red spots) were retained. The fish were quickly transported to the University of California, Davis, Bodega Marine Laboratory (BML) in aerated plastic coolers. At BML, threespine sticklebacks were kept in 100-liter rectangular fiberglass tanks receiving a constant flow (≥4 liters/minute) of 10–12°C seawater (33‰ salinity). Fish were fed *ad libitum* rations of live adult brine shrimp, *Artemia* sp., twice daily. All experimental fish fed readily in captivity and showed no visible signs of disease or stress before the experiments. All fed fish received *ad libitum* rations 2 hours before the start of the thermal preference experiment, whereas food-deprived sticklebacks received no food for 24–28 hours before the experiment.

Thermal preference experiments were conducted in an outdoor horizontal thermal gradient tank (Fig. 1A). Several previous studies have used vertical gradient tanks to investigate thermal preferences (e.g., Garside et al. 1977, Roed 1979), but the horizontal design avoids unpredictable vertical temperature stratification and reduces the influence of different water depths on behavior. For the same reasons, water depth in the gradient tank was set to 2 cm via a centrally mounted standpipe. This water depth was shallow enough to avoid any vertical thermal stratification (as determined by the addition of food coloring to the opposing warm and cold inflows) and was consistent with the shallow depths at which Bodega Harbor and other

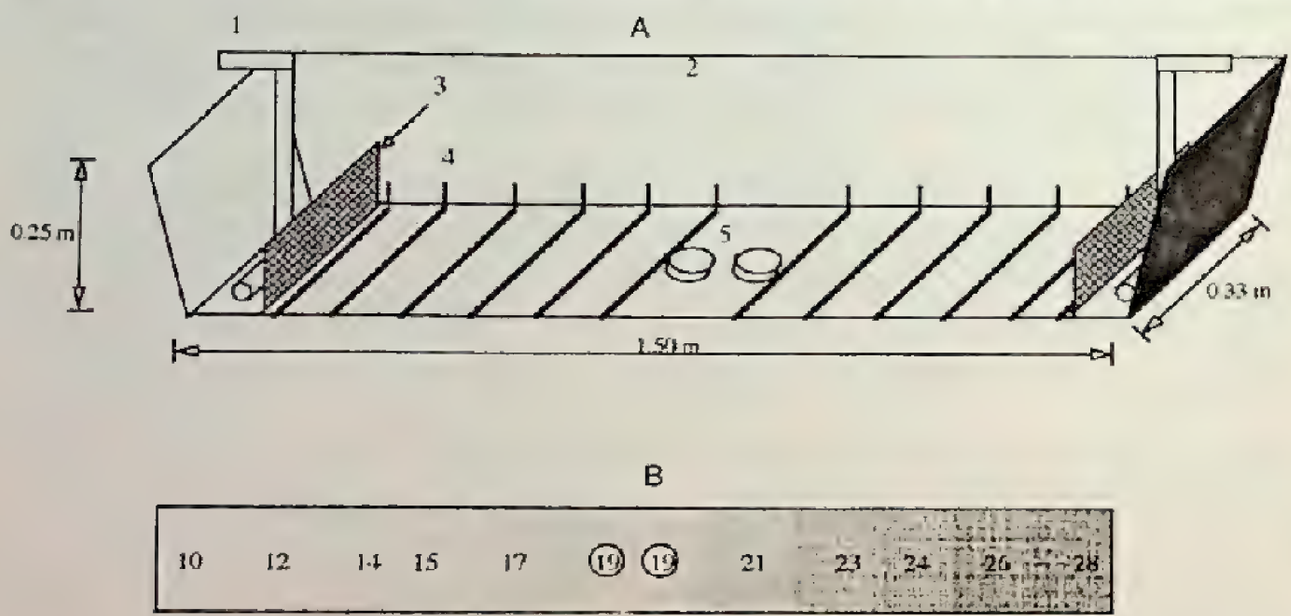


Figure 1. Schematic diagram (not to scale) of horizontal gradient tank (A), and an example of temperature (°C) distributions once the gradient was established (B).
Legend: 1. Inverted T-shaped diffusers for 10°C (cold end) or 25–30°C (heated end) water.
2. ABS plastic gradient tank.
3. Mesh screen.
4. Locations of the 12 YSI Model 401 thermistors (each solid black line).
5. Drains with standpipes set to maintain mean depth of 2 cm.

stickleback populations are commonly found (Moyle 1976). Though the water was shallow, the sticklebacks did not appear stressed by the depth, especially after the gradient tank was covered with light canvas cloth. Seawater continuously flowed (at ca. 500 ml/minute) into each end of the gradient tank via inverted T-shaped PVC diffusers. No visible food particles or organisms were observed in the clear, inflowing seawater. Cold (10–12°C) seawater entering at 1 end of the tank and heated (25–30°C) seawater entering at the other end established a 13–20°C thermal gradient (Fig. 1B). A YSI Model 44TD (Yellow Springs Instruments[1], Yellow Springs, Ohio, USA) telethermometer was used to obtain temperature readings from 12 calibrated YSI Model 401 thermistor probes placed at regular intervals in the gradient tank. Plastic screens (5-mm mesh) kept fish from using the PVC diffusers as cover, and mirrored tiles placed at a 45° angle above the gradient tank allowed observation of fish location without disturbance. In addition, light-colored canvas cloth was draped over the tank setup to exclude direct sunlight and external disturbances that might influence the fishes' movements or locations.

Thermal preference experiments were conducted during 5–11 July 1996. We measured individual thermal preferences of 11–12 fish from each treatment group. Fish were randomly netted from their holding tank, transported 30 m in a plastic bucket of ambient seawater, and quickly transferred to the gradient tank containing only ambient seawater. After a 30-minute tank acclimation period, the flow of heated seawater was started, establishing the thermal gradient. After a 1-hour gradient acclimation period, we observed the fish's location and temperature every 5 minutes during the 1-hour experimental period. Mean preferred temperatures were the means from all of the measurements during the experimental period, whereas final preferred temperatures were those measured at the end of the experimental periods. Treatment groups' morphometrics and preferred temperatures were compared using t-tests. The relation among mean preferred temperature, final preferred temperature, and body size was examined using least squares linear regression. The significance level for all statistical tests was set at $P < 0.05$.

RESULTS

Food-deprived threespine sticklebacks had significantly lower mean preferred and final preferred temperatures than fed threespine sticklebacks (Table 1). The mean final and mean preferred temperatures within each treatment group were not significantly different, although there was a significant relationship between the food-deprived fishes' final and mean preferred temperatures (Fig. 2A). However, this relationship was not significant for the fed treatment group (Fig. 2B). Threespine stickleback wet weights (range: 2.0–5.1 g) and standard lengths (range: 51–69 mm) did not differ significantly between food-deprived (n = 12) and fed (n = 11) treatment groups (Table 1). Larger (length) food-deprived sticklebacks selected lower final

[1] Use of brand names does not imply endorsement by the California Department of Fish and Game.

Table 1. Preferred temperatures and morphometrics of marine female threespine sticklebacks. All values are means ±SE. Asterisks denote statistically significant differences (P <0.05) between treatments.

Treatment	n	Weight (g)	Standard length (mm)	Preferred temperature (°C)	
				Final	Mean
Food-deprived	12	4.3±0.1	63±1	15.9*±1.1	15.8*±1.1
Fed	11	3.9±0.3	62±2	20.1*±0.8	19.0*±0.8

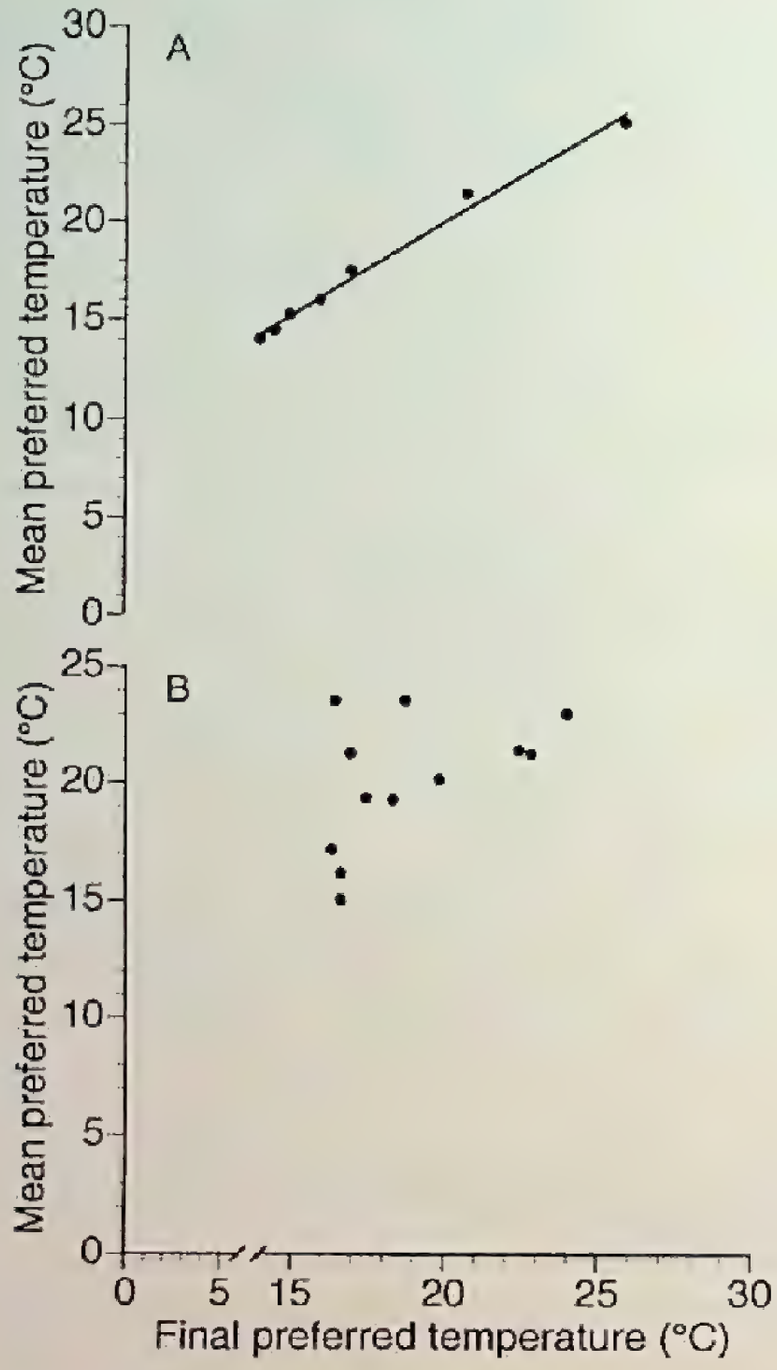


Figure 2. Relationships between mean and final preferred temperatures for food-deprived (A) and fed (B) female threespine sticklebacks. The relationship for the food-deprived treatment was statistically significant (average preferred temperature = 1.13 + 0.94 × final preferred temperature, $r^2 = 0.99$, $P < 0.001$).

and mean preferred temperatures than the smaller individuals, but this phenomenon was not observed in fed sticklebacks (Fig. 3).

DISCUSSION

Although both food-deprived and fed marine threespine sticklebacks selected final and mean preferred temperatures that were higher than their acclimation and holding temperatures, food-deprived sticklebacks preferred cooler temperatures than fed ones. This supports our hypothesis that food-deprived sticklebacks would select lower temperatures and raises the question concerning why female sticklebacks responded this way.

Two interpretations of the results seem reasonable. The 1st concerns cover-seeking behavior. Though formidably armored, threespine sticklebacks are slow moving and

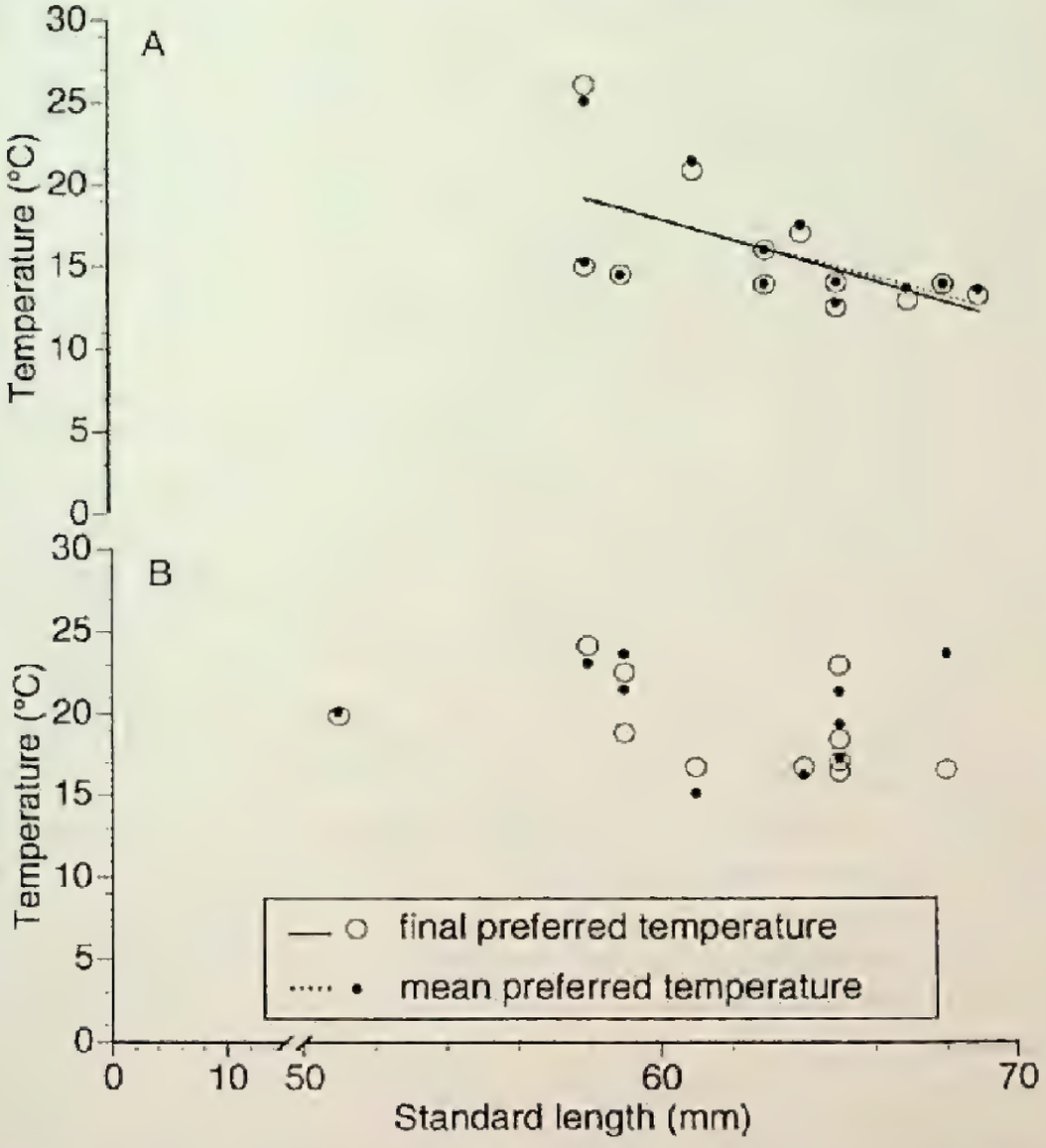


Figure 3. Size effects on mean and final preferred temperatures of food-deprived (A) and fed (B) female threespine sticklebacks. The relationships between standard length (SL) and mean preferred temperature (mean preferred temperature = 53 − 0.58 × SL, $r^2 = 0.28$) and standard length and final preferred temperature (final preferred temperature = 56 − 0.64 × SL, $r^2 = 0.30$) were significant for the food-deprived sticklebacks ($P<0.05$), but not for the fed sticklebacks ($P>0.05$).

present easy targets for aquatic and avian predators (Moyle 1976, Moyle et al. 1982). Presumably, because of their vulnerability, Bodega Harbor threespine sticklebacks are often associated with dense eel grass cover and would logically seek cover in a thermal gradient tank. In addition to the physical cover created by the screens at each end of the gradient tank, it is possible that the food-deprived sticklebacks associated the cooler water with increasing depth during these July experiments, even though the gradient tank was of uniform depth. Only 3 food-deprived fish and 2 fed fish chose locations adjacent to the screens, most likely seeking cover. Because these fishes had to select either the screen at the warm or cold end of the gradient tank, they still provided a relative measure of thermal preference. An alternate explanation for this behavior is that these fishes were trying to select even more extreme temperatures than those presented in our gradient tank, which would have led to even greater differences between the treatments.

The 2nd interpretation of our results regards the adoption of energetic, evolutionarily derived strategies to conserve energy during periods of food deprivation and to increase metabolic efficiency during periods of high food abundance. The strategy results from the thermal-dependence of most energy budget components. By selecting lower temperatures, food-deprived threespine sticklebacks lower their body temperature and reduce their maintenance metabolic costs as well as the rate of energy store depletion (reviewed by Fry 1971). The advantage of this behavioral thermoregulatory strategy is that it would increase their ability to endure during periods of low food abundance (Sogard and Olla 1996).

Threespine stickleback oxygen consumption rates increase with increasing temperatures. Cole[2] (1978) reported a mean Q_{10} of 1.82 over a 7–20°C range. Lauritzen and Cech (unpublished data) measured a mean Q_{10} of 1.60 over a 14.9–24.2°C range, and Feldmeth and Baskin's data (1977) indicate a mean Q_{10} of 1.51 over a 13.2–18.6°C range. Based on these values, food-deprived threespine sticklebacks could reduce aerobic metabolism about 17% by selecting mean temperatures that are 4.2°C lower than those selected by the fed fish. Similar food-deprivation effects have been reported for other species, such as brook trout, *Salvelinus fontinalis*; rainbow trout, *Oncorhynchus mykiss* (Javaid and Anderson 1967); shiner surfperch, *Cymatogaster aggregrata;* California grunion, *Leuresthes tenuis*, (Ehrlich et al. 1979); and walleye pollock, *Theragra chalcogramma*, (Sogard and Olla 1996). However, not all food-deprived fishes select cooler temperatures than their fed counterparts; food-deprived Atlantic salmon, *Salmo salar*, preferred warmer temperatures than fed salmon (Javaid and Anderson 1967).

The 2nd thermoregulatory strategy caused fed threespine sticklebacks to select temperatures that were twice as high as their acclimation temperature and approximately 4°C higher than those selected by the food-deprived sticklebacks in order to increase their metabolic efficiency. While increasing temperature tends to generally increase biochemical reaction rates in ectothermic fishes, not all their metabolic processes (e.g., body maintenance, growth , activity, reproduction) respond

[2] Cole, S.J. 1978. Studies on the energy budgets of two freshwater teleosts. M.S. Thesis, University of Wales, Bangor, Wales, United Kingdom.

equally to temperature changes (Brett and Groves 1979). For example, Myrick[3] (1998) found that increasing temperature from 10 to 19°C significantly increased growth rate of juvenile Little Kern River golden trout, *Oncorhynchus mykiss whitei*, but did not affect food consumption or metabolic rates to the same degree. This increased growth was attributed to an increase in food conversion efficiency (Myrick[3] 1998). Increases in temperature also tend to increase gastric evacuation rates (Brett 1971), stimulating more frequent feeding. For example, juvenile Bear Lake sculpin, *Cottus extensus*, migrated from their cold (5°C) demersal feeding areas to warmer (13–16°C) surface waters, increasing their gastric evacuation rates and allowing daily feeding. This behavior resulted in a 300% increase in growth rate over sculpins that remained at a constant 5°C (Nevermann and Wurtsbaugh 1994). By increasing the rate of food consumption, threespine sticklebacks would be able to exceed the level of energy intake necessary for maintenance metabolism and could allocate the surplus energy to other components of their energy budget, such as activity and growth, including reproductive growth (Adams and Breck 1990). These factors are of particular relevance for the Bodega Harbor population, because they were collected during the onset of their breeding season (Moyle 1976) and the females would need to assimilate energy for reproductively related growth and movements. Young fish often select temperatures consistent with maximal growth (Jobling 1981, Forseth and Jonsson 1994), but maximizing reproductive output is probably more important for mature fishes. However, increases in temperature do not automatically result in increased physiological efficiency, as described by Guderley et al. (1994) who reported that fed, mature (age 2+) threespine sticklebacks acclimated to 23°C lost weight, whereas those acclimated to 6°C gained weight.

Both food-deprived and fed threespine sticklebacks from the Bodega Harbor population selected higher mean preferred temperatures than have been reported for other marine threespine stickleback populations. Norwegian threespine sticklebacks acclimated to 10°C seawater and not fed for 48 hours preferred temperatures of 4°C (April)–8°C (October) (Roed 1979), about 8–12°C lower than our food-deprived fish. Nova Scotian threespine sticklebacks acclimated to 15°C seawater and fed during the experiment had a final preferred temperature of 17.1°C (Garside et al. 1977), about 2–3°C lower than our fish. These values may reflect genetic or acclimation temperature differences. Genetic differences may be associated with the fact that the Bodega Harbor population is one of the southernmost populations on the North American Pacific coast (Peeke[4] 1998) and as such is exposed to greater thermal fluctuations and higher mean annual temperatures than more northerly populations.

The strong relationship between food-deprived sticklebacks' mean and final preferred temperatures suggest that these fish quickly selected their preferred

---

[3] Myrick, C.A. 1998. Temperature, genetic, and ration effects on juvenile rainbow trout (*Oncorhynchus mykiss*) bioenergetics. Ph.D. Dissertation, University of California, Davis, California, USA.

[4] Peeke, H.V.S. 1998. Behavioral biology of the three-spined stickleback. Pages 34-36 *in:* 1998 Bodega Marine Laboratory Annual Report. University of California, Davis, California, USA.

temperature and then reduced their activity levels. This result may indicate an energy conservation strategy where activity metabolism is reduced due to the limited energy supply. Sogard and Olla (1996) found that walleye pollock held on intermediate-level rations were significantly more active in a thermal gradient than food-deprived fish. They attributed the higher activity levels to foraging behavior.

Conversely, our fed threespine sticklebacks did not have a significant relationship between their mean and final preferred temperatures, and their selected temperatures showed greater variability over the course of the experiment. This may reflect temperature-related increases in activity levels (Briggs and Post 1997) or may be related to the larger proportion of energy available for activity in fed fish.

We also observed fish-size-related differences in thermal preference in food-deprived sticklebacks, but not in those that were fed. Larger food-deprived threespine sticklebacks selected significantly cooler temperatures than smaller food-deprived individuals (Fig. 3). Potentially, because larger fish have greater overall metabolic demands (reviewed by Fry 1971), they select cooler temperatures under food-deprived conditions to achieve levels of metabolic savings, similar to those of smaller fish that select warmer water. Because food was not limiting for fed sticklebacks, we did not observe a size effect on thermal preference.

Threespine stickleback populations are polymorphic with respect to behavior, function, and structure on latitudinal, longitudinal, and even elevational scales (Moyle 1976, Wooton 1976). This polymorphism makes it impossible to make broad generalizations about female threespine sticklebacks' thermal preferences. Although relatively small, our study is the first to demonstrate a feeding level effect on the temperature preferences of threespine sticklebacks. It provides baseline information for future studies on stickleback thermal preference.

ACKNOWLEDGMENTS

We thank the BML staff, especially W. Borgeson, K. Brown, J. Kane, W. and J. Newman, P. Siri, and B. Tamone, for technical assistance; V. Peeke and T. Chen for technical advice; H. Zhou for statistical advice; and the California Agricultural Experiment Station (grant 3455-H to J.J. Cech) for partial research support.

LITERATURE CITED

Adams, S.M. and J.E. Breck. 1990. Bioenergetics. Pages 389-415 *in:* C.B. Schreck and P.B. Moyle, editors. Methods for fish biology. American Fisheries Society, Bethesda, Maryland, USA.

Beitinger, T.L. and L.C. Fitzpatrick. 1979. Physiological and ecological correlates of preferred temperature in fish. American Zoologist 19:319-329.

Blasco, J., J. Fernandez, and J. Guiterrez. 1992. Fasting and feeding in carp, *Cyprinus carpio* L.: The mobilization of reserves and plasma metabolite and hormone variations. Journal of Comparative Physiology B 162:539-546.

Boule, V. and G.J. Fitzgerald. 1989. Effects of constant and fluctuating temperature on egg production in the threespine stickleback (*Gasterosteus aculeatus*). Canadian Journal of Zoology 67:1599-1602.

Brandt, S.B. 1993. The effect of thermal fronts on fish growth: A bioenergetics evaluation of food and temperature. Estuaries 16:142-159.

Brett, J.R. 1971. Energetic responses of salmon to temperature: A study of some thermal relations in the physiology and freshwater ecology of sockeye salmon (*Oncorhynchus nerka*). American Zoologist 11:99-113.

Brett J.R. and T.D.D. Groves. 1979. Physiological energetics. Pages 279-352 *in:* W.S. Hoar, D.J. Randall, and J.R. Brett, editors. Fish physiology. Academic Press, New York, New York, USA.

Briggs, C.T. and J.R. Post. 1997. In situ activity metabolism of rainbow trout (*Oncorhynchus mykiss*): Estimates obtained from telemetry of axial muscle electromyograms. Canadian Journal of Fisheries and Aquatic Sciences 54:859-866.

Brio, P.A. 1998. Staying cool: Behavioral thermoregulation during summer by young-of-year brook trout in a lake. Transactions of the American Fisheries Society 127:212-222.

Cech, J.J., Jr., S.J. Mitchell, D.T. Castleberry, and M. McEnroe. 1990. Distribution of California stream fishes: Influence of environmental temperature and hypoxia. Environmental Biology of Fishes. 29:95-105.

Cherry, D.S., K.L. Dickson, and J. Cairns, Jr. 1977. Preferred, avoided and lethal temperatures of fish during rising temperature conditions. Journal of the Fisheries Research Board of Canada 34:239-246.

Dewar, H., J.B. Graham, and R.W. Brill. 1994. Studies of tropical tuna swimming performance in a large water tunnel. II. Thermoregulation. Journal of Experimental Biology 192:33-44.

Ehrlich, K.F., J.M. Hood, G. Muszynski, and G.E. McGowen. 1979. Thermal behavioral responses of selected California littoral fishes. Fishery Bulletin 76:837-849.

Feldmeth, C.R. and J.N. Baskin. 1977. Thermal and respiratory studies with reference to temperature and oxygen tolerance for the unarmored stickleback *Gasterosteus aculeatus williamsoni* Hubbs. Bulletin of the Southern California Academy of Science 75:127-131.

Forseth, T. and B. Jonsson. 1994. The growth and food ration of piscivorous brown trout (*Salmo trutta*). Functional Ecology 8:171-177.

Fry, F.E.J. 1971. The effect of environmental factors on the physiology of fish. Pages 1-98 *in:* W.S. Hoar and D.J. Randall, editors. Fish physiology. Academic Press, New York, New York, USA.

Garside, E.T., D.G. Heinze, and S.E. Barbour. 1977. Thermal preference in relation to salinity in threespine stickleback, *Gasterosteus aculeatus* L., with an interpretation of its significance. Canadian Journal of Zoology 55:590-594.

Guderley, H., B.A. Lavoie, and N. Dubois. 1994. The interaction among age, thermal acclimation and growth rate in determining muscle metabolic capacities and tissue masses in the threespine stickleback, *Gasterosteus aculeatus*. Fish Physiology and Biochemistry 13:419-431.

Hainsworth, R.F. 1981. Animal physiology: Adaptations in function. Addison-Wesley Publishing Co., Reading, Massachusetts, USA.

Hochachka, P.W. 1991. Temperature: The ectothermy option. Pages 313-322 *in:* P.W. Hochachka and T.P. Mommsen, editors. Phylogenetic and biochemical perspectives. Elsevier, Amsterdam, The Netherlands.

Hopkins, T.E. and J.J. Cech, Jr. 1994. Effect of temperature on oxygen consumption of the bat ray, *Myliobatis californica* (Chondrichthyes, Myliobatidae). Copeia 1994:529-532.

Javaid, M.Y. and J.M. Anderson. 1967. Influence of starvation on selected temperatures of some salmonids. Journal of the Fisheries Research Board of Canada 24:1515-1519.

Jobling, M. 1981. Temperature tolerance and the final preferendum: Rapid methods for the assessment of optimum growth temperatures. Journal of Fish Biology 19:439-455.

Jobling, M. 1994. Fish bioenergetics. Croon & Helm, London, United Kingdom.

Jordan, C.M. and E.T. Garside. 1972. Upper lethal temperatures of threespine stickleback *Gasterosteus aculeatus* in relation to thermal and osmotic acclimation, ambient salinity and size. Canadian Journal of Zoology 50:1405-1411.

Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J.R. Stauffer, Jr. 1980. Atlas of North American freshwater fishes. North Carolina Biological Survey Publication No. 1980-12.

Lemons, D.E. and L.I. Crawshaw. 1985. Behavioral and metabolic adjustments to low temperatures in the largemouth bass (*Micropterus salmoides*). Physiological Zoology 58:175-180.

Moyle, P.B. 1976. Inland fishes of California. University of California Press, Berkeley, California, USA.

Moyle, P.B., J.J. Smith, R.A. Daniels, T.L. Taylor, D.G. Price, and D.M. Baltz. 1982. Distribution and ecology of stream fishes of the Sacramento-San Joaquin drainage system, California. University of California Press, Berkeley, California, USA.

Nevermann, D. and W.A. Wurtsbaugh. 1994. The thermoregulatory function of diel vertical migration for a juvenile fish, *Cottus extensus*. Oecologia 98:247-256.

Randall, D.J. and A.P. Farrell, editors. 1997. Deep-sea fishes. Academic Press, San Diego, California, USA.

Reynolds, W.W. and M.E. Casterlin. 1978. Thermoregulatory behavior of brown trout, *Salmo trutta*. Hydrobiologia 62:79-80.

Roed, K.H. 1979. The temperature preference of threespined stickleback, *Gasterosteus aculeatus* L. (Pisces), collected at different seasons. Sarsia 64:137-141.

Snyder, R.J. 1991. Migration and life histories of the threespine stickleback: Evidence for adaptive variation in growth rates between populations. Environmental Biology of Fishes 31:381-388.

Sogard, S.M. and B.L. Olla. 1996. Food deprivation affects vertical distribution and activity of a marine fish in a thermal gradient: Potential energy conserving mechanisms. Marine Ecology Progress Series 133:43-55.

Somero, G.N. 1995. Proteins and temperature. Annual Reviews in Physiology 57:43-68.

Taylor, E.B. 1986. Prolonged and burst swimming in anadromous and freshwater threespine stickleback, *Gasterosteus aculeatus*. Canadian Journal of Zoology 64:416-420.

Wood, C.M. and D.G. McDonald, editors. 1997. Global warming: Implications for freshwater and marine fish. Cambridge University Press, Cambridge, United Kingdom.

Wooton, R.J. 1976. The biology of sticklebacks. Academic Press, London, United Kingdom.

Wooton, R.J. 1984. A functional biology of sticklebacks. Croon Helm, London, United Kingdom.

Wurtsbaugh, W.A. and G.E. Davis. 1977. Effects of temperature and ration level on the growth and food conversion efficiency of *Salmo gairdneri*, Richardson. Journal of Fish Biology 11:87-98.

Received: 7 February 1999
Accepted: 24 November 1999

California Fish and Game 85(3):113-117 1999

RANGE EXTENSIONS OF 3 SPECIES OF MACROURIDS FROM THE WEST COAST OF NORTH AMERICA

GERALD R. HOFF
Resource Assessment and Conservation Engineering Division
Alaska Fisheries Science Center
National Marine Fisheries Service, NOAA
7600 Sand Point Way N.E., Building #4, BIN C15700
Seattle, Washington 98115-0070
e-mail: jerry.hoff@noaa.gov

Macrourid specimens were collected during the 1996 and 1997 Alaska Fisheries Science Center (AFSC) groundfish survey on the upper continental slope (183–1,280 m) off California, Oregon, and Washington. This investigation reports on distributional records of 3 species in 3 genera (*Coryphaenoides cinereus*, popeye grenadier; *Nezumia liolepis*, smooth grenadier; and *Malacocephalus laevis*, softhead grenadier) (Fig. 1) of macrourids collected during these surveys. Trawling aboard the NOAA R/V *Miller Freeman* was conducted using a Nor'eastern bottom trawl equipped with mudsweep roller gear (Lauth[1] 1997). Fishes were deposited in the University of Washington (UW) Fish Collection. Fin ray counts and measurements from the specimens are presented in Table 1, with literature values for comparisons. Specimen description terminology follows Iwamoto and Stein (1974).

Coryphaenoides cinereus (Gilbert, 1895) is a relatively small (450 mm total length; Cohen et al. 1990) macrourid species of the North Pacific that inhabits the deep waters (630–2,832 m) of Japan, the Aleutian Islands, the Gulf of Alaska, and the west coast of North America (Iwamoto and Stein 1974, Cohen et al. 1990) south to southern Oregon at approximately 43°N (Iwamoto and Stein 1974, Cohen et al. 1990). In October 1997, 4 *C. cinereus* were collected south of 43°N with the southernmost specimen caught near Monterey Bay, California, at approximately 36°N (UW 041685, 1 specimen, 123 mm pre-anal length (PAL), 1177 m depth, 36°42'54"N, 122°17'4"W; Fig.1A). This record is approximately 650 km south of the reported limit for the species, deeper than the depth range reported for the Bering Sea (400–950 m), but within the depth range reported for Japan (720–1,860 m) (Cohen et al. 1990). Although morphometric and meristic data have been reported to be highly variable (Cohen et al. 1990), the specimen from 36°N agrees with the description of *C. cinereus* by Iwamoto and Stein (1974), which was based primarily on Alaskan and British Columbian specimens (Table 1). Description: color whitish (mostly denuded of scales), remaining scales slightly brown; gill chamber, mouth, and peritoneum dark; orbital rim light gray; snout spinule prominent; chin barbel short; suborbital shelf narrow and denuded of scales.

---

[1] Lauth, R.R. 1997. The 1996 Pacific west coast upper continental slope trawl survey of groundfish resources off Washington and Oregon: Estimates of distribution, abundance, and length composition. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS-AFSC-81.

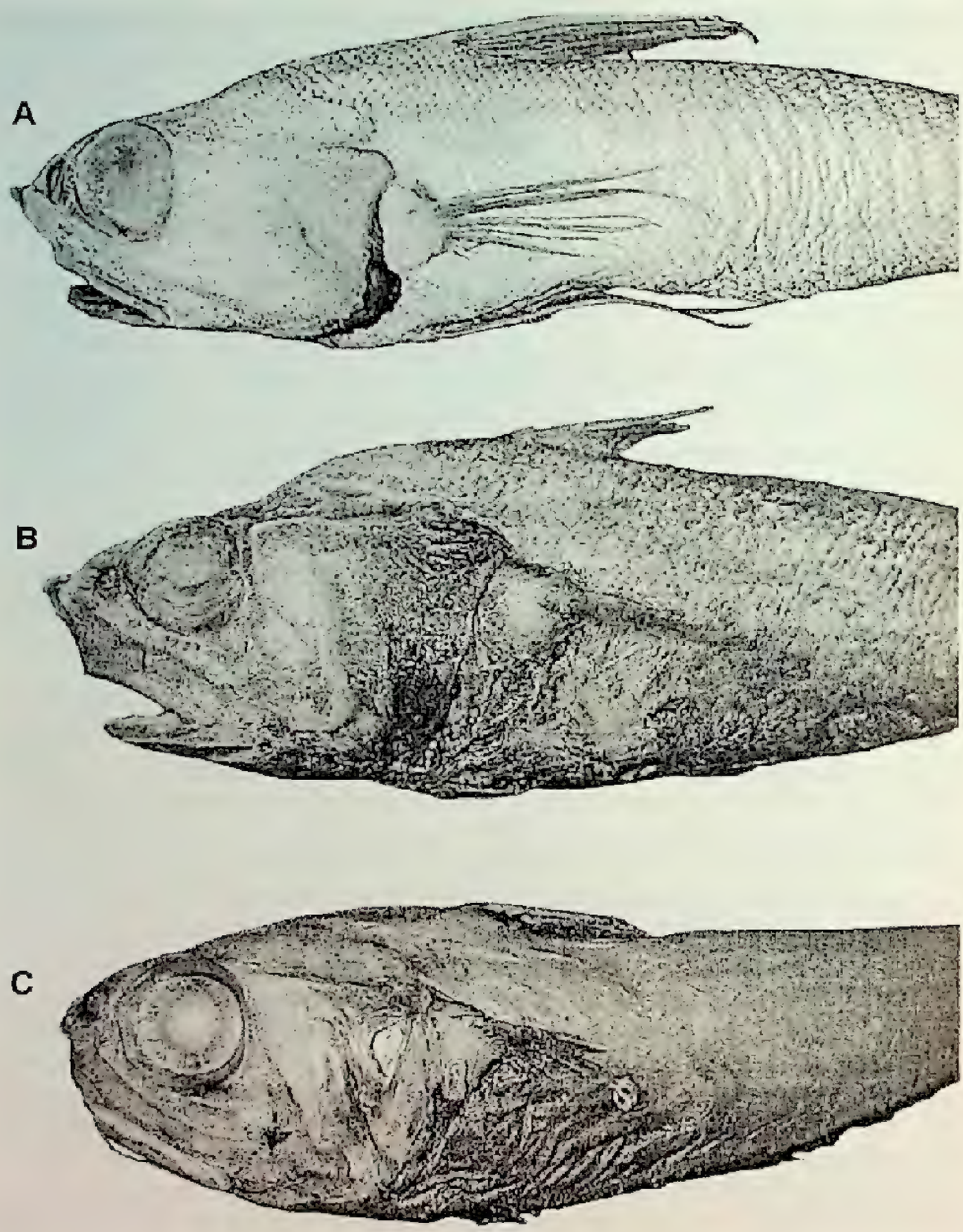


Figure 1. (A) *Coryphaenoides cinereus* (UW 041685), (B) *Nezumia liolepis* (UW 041686), and (C) *Malacocephalus laevis* (UW 041690), collected off California and Washington in 1996–1997.

The 3 other specimens collected south of Oregon in 1997 suggest that *C. cinereus* may not be uncommon as far south as central California; (UW 041693, 2 specimens, 88 and 91 mm PAL, 1007 m depth, 40°25'39"N, 124°40'17"W; tissue sample only AFSC uncataloged, 1 specimen, 100 mm PAL, 953 m depth, 39°58'32"N, 124°22'54"W).

Nezumia liolepis (Gilbert, 1890) is a small macrourid common from Monterey Bay, California to Baja California at 201–1,655 m (Iwamoto and Stein 1974, Iwamoto 1979, Cohen et al. 1990). The species has been reported to occur from about 36°N to the Gulf of California (Cohen et al. 1990). In October 1996 and 1997, 5 *N. liolepis* were caught north of 36°N with the northernmost record at approximately 46°N (UW 041686, 2 specimens, 65 and 72 mm PAL, 755 m depth, 45°57'38"N, 124°52'42"W; Fig. 1B). This record extends the known range for the species north by approximately 900 km from central California to southern Washington. The 2 specimens of *N. liolepis* described here agree with the description of Iwamoto and Stein (1974) and Iwamoto (1979) (Table 1). Description: color blue-brown with darker blue-black coloration ventrally on belly and branchiostegal region, pelvic and pectoral fins dark, dorsal fins lighter in color; head and body mostly denuded of scales; snout rounded and head laterally compressed with a low broad suborbital shelf; anus midway between anal fin origin and pelvic fin insertions; small fossa possibly located anterior of the anus (belly on both specimens damaged); elongated dorsal spine mostly smooth, several very small serrations throughout its length. Both specimens were female.

The additional specimens collected north of 36°N suggest *N. liolepis* may not be uncommon as far north as Washington (UW 041689, 1 specimen, 70 mm PAL, 1059 m depth, 43°6'57"N, 124°59'26"W; UW 041687, 1 specimen, 45 mm PAL, 839 m depth, 41°44'41"N ,124°45'34"W; UW 041688, 1 specimen, 60 mm PAL, 953 m depth, 39°58'32"N, 124°22'54"W).

Malacocephalus laevis (Lowe, 1843) is common throughout the Atlantic and Indian oceans in shallow slope waters (300–700 m) (Cohen et al. 1990). Specimens tentatively identified as *M. laevis* have been collected in the eastern Pacific Ocean off Santa Barbara, California, around seamounts off Baja California (Iwamoto 1979), and off Chile (Sazonov and Iwamoto 1992). In October 1997, an individual was caught south of Monterey Bay near Point Sur, California (UW 041690, 1 specimen, 417 m depth, 36°18'38"N, 122°6'21"W; Fig.1C), approximately 200 km north of the previous record for *M. laevis* from off Santa Barbara, California, and the most northern east Pacific specimen collected to date. The new specimen agrees with the description given by Iwamoto (1979) of the single Santa Barbara *M. laevis*, and 84 specimens collected from the Nazca and Sala y Gomez ridges off Peru (Sazonov and Iwamoto 1992) (Table 1). Description: color light brown (denuded of scales) with darker blue-black belly; head laterally compressed with low sub-orbital ridge and rounded snout; fossa small and bean-shaped between pelvic fin insertions, additional fossa just anterior to anus; anus anterior of anal fin insertion; elongated dorsal spine smooth, without serrations; outer branchiostegal rays heavily scaled throughout length; gular area lacking scale patch; upper jaw with 2 rows of small teeth.

Table 1. Meristic and morphometric comparisons of *Coryphaenoides cinereus*, *Nezumia liolepis*, and *Malacocephalus laevis* from specimens collected off California and Washington in 1996–1997 and literature values for each species. Specimen numbers in column headings are University of Washington collection numbers. I&S is Iwamoto and Stein, I is Iwamoto, S&I is Sazanov and Iwamoto.

	Coryphaenoides cinereus		*Nezumia liolepis*		*Malacocephalus laevis*		
	UW 041685	I&S (1974)	UW 041686	I(1979)	UW 041690	I(1979)	S&I (1992)
Number of specimens	1	20	2	38	1	1	18
Meristics							
Dorsal soft rays	10	10–14	8–9	8–11	11	11	10–13
Pectoral rays	18	17–23	20–22	20–25	18	20–19	16–20
Pelvic rays	8	8–10	10–11	10–12	9	8–9	8–10
Gill rakers inner 1st arch	13		9–10	9–12	10	12	10–13
Pyloric caeca	7	5–7	24–25	25–37			
Scale rows D1–lateral line	11	8–11		8–10	12	16	
Lengths							
Head length (mm)	83	39–94	49–51	26–63	54	58	37.5–79.0
Pre-anal length (mm)	123		65–72		62		
Total length (mm)		217–560		114–290	315	335	231–458
Morphometrics (% head length)							
Snout length	24	25–29	24–5	24–28	24	26	22.6–29.6
Orbit diameter	27	23–34	27–27	25–31	35	36	29.8–36.7
Interorbital width	27	24–30	22–23	21–27	27	27	26.6–34.7
Upper jaw length	37	35–41	33–35	28–40	46	48	47.1–53.5
Chin barbel length	7	2–8	11–12	10–20	19	17	19.5–32.0
Pyloric caeca length	14		14–15				
Pelvic fin length	91	67–141	44–48	42–55			30–38
Pectoral fin length	66	62–84	46	43–53			53–56
1st dorsal fin height	83	85–105	53–55	58–73			40–69
Interdorsal length	18	13–20	30–39	28–48	60	48	40–69
Internasal width	21	21–25	22–23	17–23	18	17.5	
Body depth	67	65–87	75–78	60–82	81	85	74.4–91.6
Internasal width	21	21–25	22–23	17–23	18	17.5	
Body depth	67	65–87	75–78	60–82	81	85	74.4–91.6

ACKNOWLEDGMENTS

I thank B. Flerxs, R. Lauth, and J. Orr (Alaska Fisheries Science Center, Seattle, Washington) and the crew and scientific parties of the NOAA R/V *MILLER FREEMAN* for their aid in collecting specimens. I also thank R. Harrison, R. Lauth, J. Orr, G. Stauffer, and G. Walters (Alaska Fisheries Science Center, Seattle, Washington), and D. Markle (Oregon State University, Corvallis, Oregon) for reviewing the manuscript; T. Iwamoto (California Academy of Sciences, San Francisco, California) for the loan of museum specimens; S. Barbeaux (Alaska Fisheries Science Center, Seattle, Washington) for the photographs; and T. Pietsch and B. Urbain (University of Washington Fish Collection, Seattle, Washington) for museum curation and the handling of loaned specimens.

LITERATURE CITED

Cohen, D.M., T. Inada, T. Iwamoto, and N. Scialabba. 1990. FAO species catalogue. Gadiform fishes of the world (Order Gadiformes). An annotated and illustrated catalogue of cods, hakes, grenadiers and other gadiform fishes known to date. Food and Agriculture Organization of the United Nations Synopsis 125:10.

Iwamoto, T. 1979. Eastern Pacific macrourine grenadiers with seven branchiostigal rays (Pisces:Macrouridae). Proceedings of the California Academy of Sciences 42:135-179.

Iwamoto, T. and D.L. Stein. 1974. A systematic review of the rattail fishes (Macrouridae: Gadiformes) from Oregon and adjacent waters. Occasional Papers of the California Academy of Sciences 111:1-79.

Sazonov, Y.I. and T. Iwamoto. 1992. Grenadiers (Pisces, Gadiformes) of the Nazca and Sala Y Gomez ridges, southeastern Pacific. Proceedings of the California Academy of Sciences 48:27-95.

Received: 8 March 1999
Accepted: 25 May 1999

California Fish and Game 85(3):118-120 1999

FIRST EASTERN PACIFIC RECORD OF THE GOBLIN SHARK, *MITSUKURINA OWSTONI* (LAMNIFORMES: MITSUKURINIDAE)

JOHN K. UGORETZ
California Department of Fish and Game
330 Golden Shore, Suite 50
Long Beach, California 90802

JEFFREY A. SEIGEL
Natural History Museum of Los Angeles County
900 Exposition Boulevard
Los Angeles, California 90007

The goblin shark, *Mitsukurina owstoni* Jordan, 1898, is a poorly known but widely distributed shark found in upper slope and outer continental shelf waters. Previous records are from Europe (France and Portugal), northwest Africa (Madeira), South Africa (Atlantic and Indian oceans), Guiana (based on an oral communication as noted in Quero 1972), Australia, New Zealand, and Japan (Compagno 1984, Stevens and Paxton 1985, Last and Stevens 1994, Duffy 1997).

On 20 October 1998, a male goblin shark was caught in a drift gill net set 13 km off San Clemente Island, California (32°45'N, 118°13'W) by the commercial swordfish and shark fishing vessel *GOLD COAST*. Due to storage limitations on the boat, the goblin shark's body was discarded. The head was deposited in the Natural History Museum of Los Angeles County Ichthyology Collection (LACM 47362-1) and constitutes the 1st eastern Pacific record of *M. owstoni*. It was frozen for 1 month prior to preservation in 10% formalin and storage in 70% ethanol.

Previous captures have predominately been from deep water between 300 and 1300 m (Kobayashi et al. 1982, Compagno 1984, Stevens and Paxton 1985, Stewart and Clark 1988, Yanagisawa 1991, Last and Stevens 1994). The described specimen, caught "about half-way down" a gill net set between 12 m and 47 m (D. Krebs, skipper *GOLD COAST*, personal communication), is one of a few from relatively shallow water. Though the net was set in the upper water column, it was also on the edge of a submarine canyon. Water depth in the canyon drops rapidly from around 200 m to over 2000 m. Similar shallow captures occurred in 1975 when 2 specimens were taken at a depth of 40 m off the Izu Islands, Japan (Duffy 1997).

The shark was initially identified by the presence of the long, flat, blade-like snout, highly protrusible jaws, and pointed teeth (Fig. 1). Though the shark's body was discarded after capture, the flesh was described as "flabby and grayish-brown," and the head was photographed prior to freezing. The shark was "regurgitating squid" as it was hauled aboard (D. Krebs, personal communication).

The fishermen estimated the shark's total length (TL) as 2.7 m. The head was measured and its length compared to head and body lengths of 3 goblin shark specimens of similar size (Stevens and Paxton 1985) to estimate total length. The

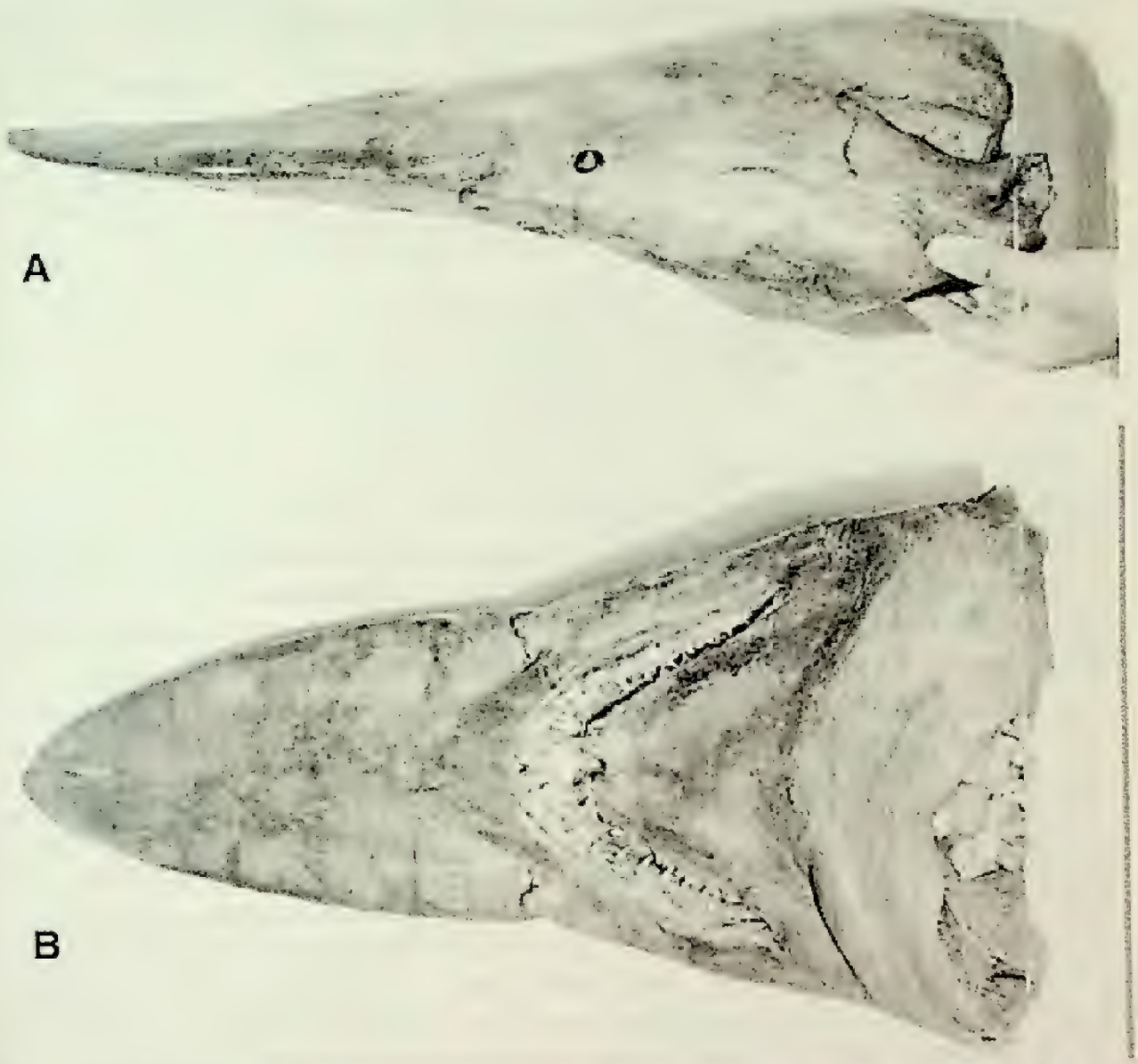


Figure 1. Lateral (A) and ventral (B) views of the head of the male goblin shark, LACM 47362-1, captured off San Clemente Island, California on 20 October 1998. Photos by R. Meier, Los Angeles County Museum.

comparison yielded an estimated total length between 2.18 m and 3.75 m (mean = 3.26 m) for the specimen (Table 1).

Tooth morphology and counts vary widely in the goblin shark (Stevens and Paxton 1985, Duffy 1997). Total tooth counts for this specimen are 38 upper and 38 lower teeth (tooth count formulae: 3+,11-3-3-12, 6+/6+, 9-3-3, 10, 7+). Duffy (1997) discussed the methodology of this tooth-count formula (see also Bass et al. 1975) and noted the difficulty in counting the posterior-most teeth in each jaw. There are drastic variations in tooth size and morphology in goblin sharks. The anterior and lateral teeth are long, slender and lanceolate (with or without basal cusps), whereas the posterior teeth are small, low-crowned, and spatulate. The posterior-most teeth in this specimen lie lingual to the last functional tooth and are not included in counts.

Table 1. Measurements of the male goblin shark head (LACM 47362-1) and conversion to TL based on 3 sharks of similar length measured in Stevens and Paxton (1985).

Measurement	Distance (mm)	Percent of TL[a]	Estimated TL (m)
Snout to inner nostrils	338	10.0	3.38
Snout to eye	407	11.8–13.3	3.06–3.45
Snout to mouth	333	9.9	3.36
Mouth width	210	5.6–6.0	3.5–3.75
Eye diameter	24	0.7–1.1	2.18–3.43

[a] From Stevens and Paxton

ACKNOWLEDGMENTS

We thank D. Krebs, skipper of the F/V *GOLD COAST*, and his crew for making the specimen available and T. Rothans and the rest of the staff at the City of San Diego Ocean Monitoring Program for storing the specimen at their facility. We also thank California Department of Fish and Game Warden D. Sforza for bringing this capture to our attention and J. Marks, M. Marks, and the staff at the Rancho Park Veterinary Clinic for the use of their x-ray machine.

LITERATURE CITED

Bass, A.J., J.D. D'Aubrey, and N. Kistnasamy. 1975. Sharks of the east coast of southern Africa IV. The families Odontaspididae, Scapanorhynchidae, Isuridae, Cetorhinidae, Alopiidae, Orectolobidae and Rhiniodontidae. Investigational Report of the Oceanographic Research Institute 39:1-102.

Compagno, L.J.V. 1984. FAO species catalogue. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 1. Hexanchiformes to Lamniformes. FAO (United Nations Food and Agriculture Organization) Fish Synopsis (125) Volume 4, Part 1.

Duffy, C.A.J. 1997. Further records of the goblin shark, *Mitsukurina owstoni* (Lamniformes: Mitsukurinidae), from New Zealand. New Zealand Journal of Zoology 24:167-171.

Kobayashi, H., Y. Yamaguchi, T. Nonoda, K. Izawa, and H. Ban. 1982. The sharks caught on the continental shelf and slope in the Kumano Nada Region along the Pacific coast of Japan. Bulletin of the Faculty of Fisheries, Mie University 9:101-123.

Last, P.R. and J.D. Stevens. 1994. Sharks and rays of Australia. CSIRO (Commonwealth Scientific and Industrial Research Organization) Division of Fisheries, Australia.

Quero, J.C. 1972. Capture de deux *Scapanorhynchus owstoni* (Jordan, 1898) (Selachii, Scapanorhynchidae) par des chalutiers de la Rochelle. Annales de la Societe des Sciences Naturelles de la Charente-Maritime 5:168-170.

Stevens, J.D. and J.R. Paxton. 1985. A new record of the goblin shark, *Mitsukurina owstoni* (Family Mitsukurinidae), from eastern Australia. Proceedings of the Linnean Society of New South Wales 108:37-45.

Stewart, A.L. and M.R. Clark. 1988. Records of three families and four species of fish new to the New Zealand fauna. New Zealand Journal of Zoology 15:577-583.

Yanagisawa, F. 1991. Notes of the oral morphology of goblin shark, *Mitsukurina owstoni* Jordan. Nanki Seibutsu 33:10-14.

Received: 5 April 1999
Accepted: 27 June 1999

California Fish and Game 85(3):121-123 1999

NORTHERNMOST OCCURRENCE OF THE SLENDER TUNA, *ALLOTHUNNUS FALLAI*, IN THE PACIFIC OCEAN

KURT M. SCHAEFER
Inter-American Tropical Tuna Commission
8604 La Jolla Shores Drive
La Jolla, California 92037-1508
e-mail: kschaefer@iattc.ucsd.edu

JOHN CHILDERS
Southwest Fisheries Science Center
National Marine Fisheries Service, NOAA
P.O. Box 271
La Jolla, California 92038

The slender tuna, *Allothunnus fallai*, is an epipelagic species with a circumglobal distribution in the southern ocean from about 20–50°S (Collette and Nauen 1983). The exceptions to this distributional range are 2 previously reported occurrences from the North Pacific; 1 individual, 722 mm fork length (FL), from Los Angeles Harbor, California, (33°46'N, 118°11'W; Fitch and Craig 1964) and a 2nd individual, 219 mm standard length from the stomach of a sailfish, *Istiophorus platypterus*, caught in the western tropical Pacific southeast of Palau Island (5°06'N, 136°20'E; Mori 1972). The northernmost documented occurrence of slender tuna in the Pacific Ocean is recorded in this note.

The specimen, 862 mm FL and 12.1 kg, was caught jig fishing for albacore tuna, *Thunnus alalunga*, by the commercial troller *WENDY SEAA* on 25 July 1997 in the North Pacific subarctic gyre (44°01'N, 151°13'W) at a sea-surface temperature of 15.8°C. Also, 462 albacore were caught by the *WENDY SEAA* that day, in the same vicinity, and their stomach contents revealed they had been feeding on euphausiids and small cephalopods. These invertebrates are primary components of the diet of slender tuna in the South Pacific (Yatsu 1995). The specimen was collected by the junior author, who was on board the vessel at the time as a scientific observer. The specimen is deposited in the U.S. National Museum of Natural History, Washington, D.C. (USNM 352456).

The morphometric and meristic characters for the specimen are given in Tables 1 and 2. The measurements and counts follow the methods of Collette and Chao (1975). The external characters agree with descriptions of slender tuna by Serventy (1948), Collette and Chao (1975), and Collette and Nauen (1983). The elongate and rounded shape; dark blue dorsal and silver lateral and ventral coloration; and absence of dorsal, lateral, or ventral markings are characteristic of this species. Also, the distribution of scales, pectoral fin length, and length of the first dorsal fin on this specimen agree with descriptions of this species.

The internal characters also agree with descriptions of slender tuna by Serventy (1948), Collette and Chao (1975), and Collette and Nauen (1983). A total gill raker

Table 1. Summary of morphometric data for the specimen of slender tuna from the North Pacific.

Character	Measurements (mm)
Fork length	862
Head length	229
Snout–1st dorsal fin	292
Snout–2nd dorsal fin	553
Snout–anal fin	561
Snout–ventral fin	251
Maximum body depth	207
Maximum body width	152
1st dorsal fin–ventral fin	184
1st dorsal fin–anal fin	361
Ventral fin–vent	323
Base 1st dorsal fin	259
Base 2nd dorsal fin	62.3
Base anal fin	60.6
Pectoral fin length	111
Anal fin length	89.8
Diameter of iris	24.8
Maxilla length	80.7
Snout–posterior of eye	114

Table 2. Summary of meristic data for the specimen of slender tuna from the North Pacific.

Character	Counts
Dorsal spines	17
2nd dorsal rays	13
Dorsal finlets	7
Anal rays	13
Anal finlets	7
Pectoral rays	26
Vertebrae	41
Gill rakers	23+1+50 = 74

count of 70–80 and the presence of villous teeth on the rakers are unique among scombrids and are diagnostic of this species. Our specimen had 74 total gill rakers and distinct villous teeth on the rakers. Exact counts of numerous very small conical teeth on the upper and lower jaws were not possible because of extensive damage to the jaws, apparently as a result of capture. There was no swimbladder. The specimen was female and the ovaries appeared inactive. Radiographs indicated 41 total vertebrae, including the ural centrum. The 1st closed haemal arch appears to occur on the 15th vertebra, but it is not possible to ascertain the presence of the 1st haemal spine from the radiographs. Serventy (1948) also reported 41 total vertebrae for this species, but suggested some uncertainty in that count and warned that his radiograph was indistinct near the skull. Collette and Chao (1975) reported all 7 specimens

examined to have 20 precaudal plus 19 caudal vertebrae for a total of 39 vertebrae. Collette and Nauen (1983) incorrectly report that the slender tuna have 20 caudal vertebrae and a total of 40 vertebrae (B.B. Collette, National Marine Fisheries Service, personal communication).

This occurrence of slender tuna represents a significant northern range extension for the species, but should be considered a rare event. Slender tuna make seasonal migrations from subantarctic and transitional waters to subtropical waters, coupled to the seasonal geographic shifts in biomass of epipelagic subantarctic zooplankton (Yatsu 1995). Slender tuna appear to spawn in subtropical waters and in the Peru Current, from approximately 20 to 30°S, during October through December at sea-surface temperatures of 17–25°C (Watanabe et al. 1966, Yatsu 1995). The specimen of slender tuna reported here either continued on a northward course following a seasonal migration or perhaps never migrated southward to subantarctic waters as a developing juvenile, swimming to the northern hemisphere instead. Subarctic epipelagic waters are similar in physical and biological attributes to those of the subantarctic. This occurrence of slender tuna, in association with albacore, is probably attributed to similarities in schooling behavior and habitat preferences of the 2 species.

ACKNOWLEDGMENTS

We thank the owner, M. Brown, and crew of the *WENDY SEAA* for donating the specimen, and W. Bayliff, B. Collette, D. Margulies, and J. Orsi for reviewing the manuscript.

LITERATURE CITED

Collette, B.B. and L.N. Chao. 1975. Systematics and morphology of the bonitos (*Sarda*) and their relatives (Scombridae, Sardini). Fishery Bulletin 73:516-625.

Collette, B.B. and C.E. Nauen. 1983. FAO species catalogue. Scombrids of the world. An annotated and illustrated catalogue of tunas, mackerels, bonitos, and related species known to date. Food and Agriculture Organization of the United Nations, Fisheries Synopsis Number 125, 2:26-27.

Fitch, J.E. and W.L. Craig. 1964. First records for the bigeye thresher (*Alopias superciliosus*) and the slender tuna (*Allothunnus fallai*) from California, with notes on eastern Pacific scombrid otoliths. California Fish and Game 50:195-206.

Mori, K. 1972. Records of juveniles of slender tuna, *Allothunnus fallai*, from the equatorial western Pacific and the South Atlantic oceans. Japanese Journal of Ichthyology 19:29-31.

Serventy, D.L. 1948. *Allothunnus fallai*, a new genus and species of tuna from New Zealand. Records of the Canterbury Museum, New Zealand 5:131-135.

Watanabe, H., M. Yukinawa, S. Nakazawa, and S. Ueyanagi. 1996. On the larva probably referable to slender tuna, *Allothunnus fallai* Serventy. Report of Nankai Regional Fisheries Research Laboratory 23:85-94.

Yatsu, A. 1995. The role of slender tuna, *Allothunnus fallai*, in the pelagic ecosystems of the South Pacific Ocean. Japanese Journal of Ichthyology 41:367-377.

Received: 30 March 1999
Accepted: 24 June 1999

California Fish and Game 85(3):124-129 1999

PREDATION BY JUVENILE HATCHERY SALMONIDS ON WILD FALL CHINOOK SALMON FRY IN THE LEWIS RIVER, WASHINGTON

SHANE W. HAWKINS and JACK M. TIPPING
Washington Department of Fish and Wildlife
600 Capitol Way North
Olympia, Washington 98501-1091
e-mail: hawkiswh@dfw.wa.gov

Hatchery fish are released in many Pacific Northwest rivers to mitigate for lost habitat due to construction of dams. Such is the case on the Lewis River, Washington, where 2 hatcheries release coho salmon, *Oncorhynchus kisutch*; spring chinook salmon, *O. tshawytscha*; steelhead, *O. mykiss*; and sea-run cutthroat trout, *O. clarki*, as mitigation for lost habitat caused by 3 dams on the river. However, fall chinook salmon are managed for wild production. This stock has remained relatively healthy while other lower Columbia River stocks have declined in the last decade (Washington Department of Fish and Wildlife spawning ground surveys, Vancouver, Washington, USA). Fall chinook salmon spawning escapements on the Lewis River averaged 10,801 fish from 1988 to 1997 compared to 12,618 for 1964–1970 (Hawkins[1] 1998). Reasons for the relative health of the Lewis River stock include unique migration attributes and associated reduced vulnerability to marine fisheries and good water quality downstream of the 3 dams (McIsaac[2] 1990). All lower Columbia River wild chinook salmon, including those in the Lewis River, were listed as threatened under the Endangered Species Act in March 1999 (NMFS[3] 1999).

A concern in protecting Lewis River wild fall chinook salmon has been the possible negative influence of hatchery fish, including predation by hatchery salmonids. On upper Columbia River tributaries, 0.0 to 0.18% of hatchery steelhead smolts contained juvenile chinook salmon (Cannamela[4] 1993, Martin et al.[5] 1993,

[1] Hawkins, S. 1998. Results of sampling the Lewis River natural spawning fall chinook populations in 1997. Columbia River Progress Report Number 98-7. Washington Department of Fish and Wildlife, Vancouver, Washington, USA.

[2] McIsaac, D.O. 1990. Factors affecting the abundance of 1977–1979 brood wild fall chinook salmon in the Lewis River, Washington. Ph.D. Dissertation, University of Washington, Seattle, Washington, USA.

[3] NMFS (National Marine Fisheries Service). 1999. Final rule: Endangered and threatened species: Threatened status for three chinook salmon evolutionarily significant units (ESUs) in Washington and Oregon, and endangered status for one chinook salmon ESU in Washington. Federal Register, 24 March 1999, 64(56):14308-14348.

[4] Cannamela, D.A. 1993. Hatchery steelhead smolt predation of wild and natural juvenile chinook salmon fry in the upper Salmon River, Idaho. Idaho Department of Fish and Game, Boise, Idaho, USA.

[5] Martin, S W., A E. Viola, and M.L. Schuck. 1993. Investigations of the interactions among hatchery reared summer steelhead, rainbow trout, and wild spring chinook salmon in Southeast Washington. Washington Department of Wildlife #93-4, Olympia, Washington, USA.

Jonasson[6] 1995). In the Cedar River, Washington, hatchery steelhead showed no evidence of preying on sockeye salmon, *O. nerka*, fry, but juvenile wild steelhead consumed an estimated 15% of emergent sockeye salmon fry (Beauchamp 1995). Vander Haegen et al. (1998) found that only a small fraction of adult hatchery steelhead consumed salmonid juveniles in the Cowlitz River, Washington.

Hatchery coho salmon smolts are known to consume pink salmon, *O. gorbuscha*, fry (Crain[7] 1992), and pink and chum salmon, *O. keta*, fry (Johnson[8] 1973). A total of 0.16% and 0.17% of hatchery coho salmon smolts contained wild chinook fry in the Yakima River, Washington in 1997 and 1998, respectively (J. McConnaughey, Yakima Fisheries Center, Yakima, Washington, personal communication). Sea-run cutthroat trout are thought to be feeding generalists, taking advantage of available food items (Trotter 1997).

The goal of this study was to determine the number of salmonid fry consumed per hatchery smolt in the Lewis River, Washington. High levels of predation could result in hatchery operational changes.

The upstream terminus for anadromous fish on the Lewis River is Merwin Dam (river km [rkm] 31.4); Merwin Hatchery is at rkm 30.6 and Lewis River Hatchery is at rkm 25.3 (Fig. 1). The Lewis River enters the lower Columbia River at rkm 140.

Most Lewis River wild fall chinook salmon spawn at rkm 18.5–31 from October to March with a peak in November. Fry emerge from late winter through summer, peaking in late April and early May. Pre-smolts, fish >55 mm fork length, peak in abundance in late June and early July (McIsaac[2] 1990). Juvenile rearing is concentrated between rkm 11 and 25.

The Lewis River Hatchery releases spring chinook and coho salmon in the river at the hatchery site, whereas Merwin Hatchery trucks steelhead and sea-run cutthroat trout to lower river sites (rkm 25 and 10) for release. About 3,000,000 coho salmon smolts (30 g) are released in April–June, 1,200,000 spring chinook salmon smolts (90 g) are released in February–March, and 300,000 steelhead (75 g) and 25,000 sea-run cutthroat trout (90 g) are released in April–May.

Three times in spring and summer 1995, once in 1996, 15 times in 1997, and 6 times in 1998, a 30.5 m beach seine, and occasionally a 10.4 m stick seine, were used to collect hatchery salmonids at 9 sites throughout the wild chinook salmon fry rearing area. Hatchery origin steelhead and sea-run cutthroat trout were identified by the absence of the adipose fin, removed while in the hatchery. For coho salmon, 1995 and 1996 samples were biased for larger smolts and are excluded. In 1997 and 1998, most hatchery coho salmon were adipose fin-clipped; unclipped fish were coded-wire tagged as part of another study. A wire-tag wand detector (Northwest

---

[6] Jonasson, B.C., R.W. Carmichael, and T.A. Whitesel. 1995. Residual hatchery steelhead: Characteristics and potential interactions with spring chinook salmon in Northeast Oregon. Oregon Department of Fish and Wildlife, Portland, Oregon, USA.

[7] Crain, P.V. 1992. Predation by planted hatchery reared coho salmon smolts on native pink salmon fry. M.S. Thesis, University of Washington, Seattle, Washington, USA.

[8] Johnson, R.C. 1973. Potential interspecific problems between hatchery coho smolts and juvenile pink and chum salmon. Washington Department of Fisheries, Olympia, Washington, USA.

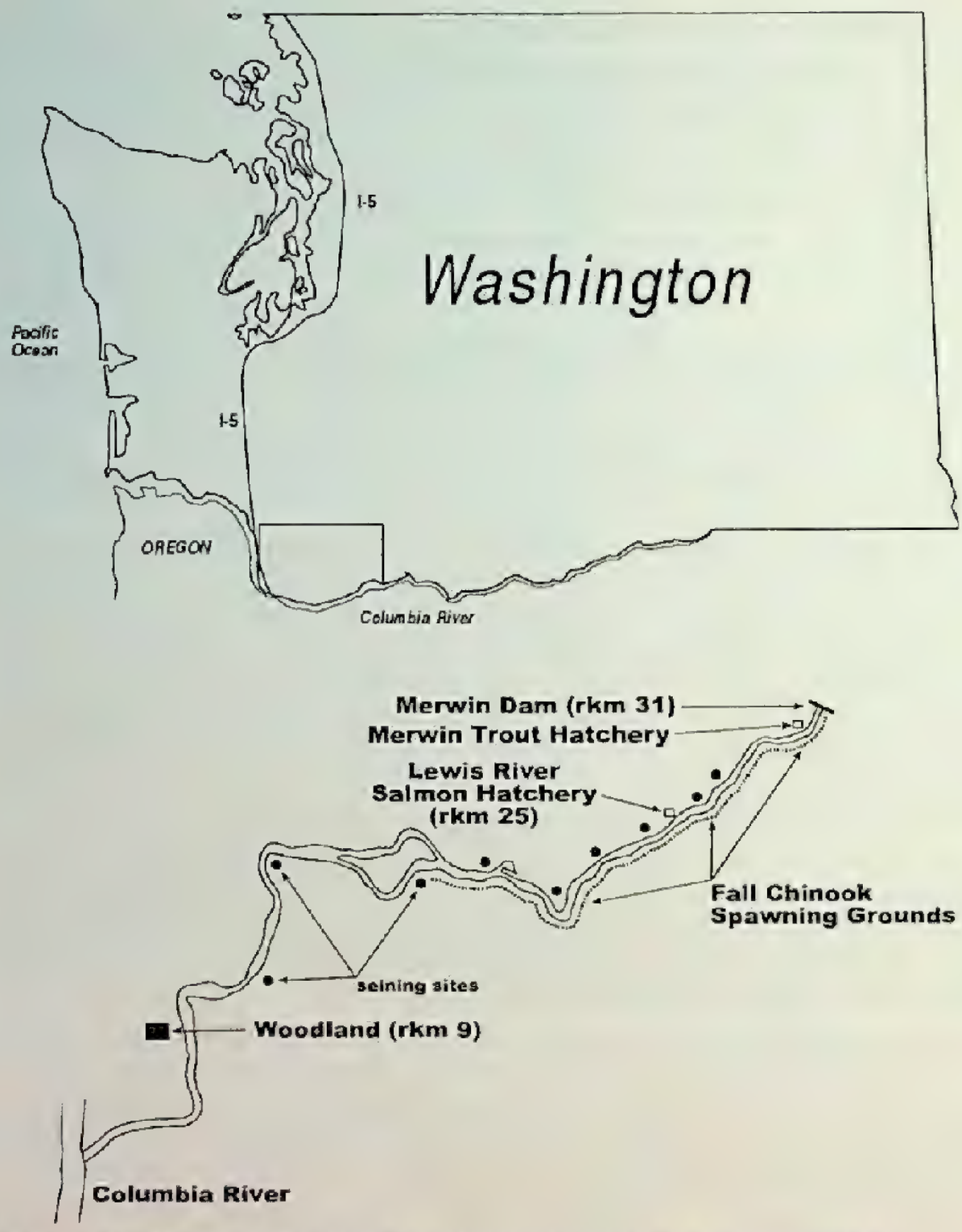


Figure 1. Seine sampling sites for juvenile salmonids on the Lewis River, Washington.

Marine Technology[9], Shaw Island, Washington, USA) was used to identify unclipped hatchery fish.

Captured hatchery smolts were anesthetized with MS-222 (tricaine methanesufonate). Stomach contents were extracted by gastric lavage with a small 12-V bilge pump with a hose connected to a stainless steel turkey baster with a blunted

[9] Use of trade names does not imply endorsement by the California Department of Fish and Game.

needle. This provided a continuous flow of water to flush stomach contents onto a fine-mesh screen for visual inspection. With 2 exceptions, species, origin, fork length and number of salmonids consumed was recorded for each fish; lengths of steelhead and sea-run cutthroat trout consuming prey were not recorded in 1995 and 1996 and the single sea-run cutthroat sampled in 1997 was not measured. Prey items were visually identified to species when possible. Only partially digested salmonid juveniles were counted as consumed prey; freshly consumed fish may have been eaten during seining. Predation rates represent the total number of fry observed divided by the smolts sampled. Student's t-test was used to compare length of sampled smolts to length of those consuming fry ($a = 0.05$).

Ninety-six percent of the 128,000 fish captured over the 4 years were juvenile wild chinook salmon. For fry captured in 1997–1998, chinook salmon, coho salmon, chum salmon and steelhead or cutthroat trout accounted for 92.7%, 6.4%, 0.4% and 0.5% of the total, respectively. Stomach contents were extracted from 1,656 hatchery coho salmon, 232 hatchery steelhead, and 20 hatchery sea-run cutthroat trout smolts. Spring chinook smolts were not encountered while seining. All identified salmonid remains were juvenile wild chinook salmon. Relatively few hatchery smolts contained fry, but those individuals often contained more than 1 (Table 1). Mean contents ranged from 0.05 to 0.11 fry per hatchery coho salmon stomach, 0.01 to 1.13 fry per steelhead stomach, and 0.00 to 2.13 fry per cutthroat trout stomach. Captured wild smolts also contained fry; 0.23 fry per coho salmon ($n = 228$), 0.17 fry per steelhead ($n = 140$), and 2.18 fry per cutthroat trout ($n = 38$).

With exception of the coho salmon sampled in 1997, length of hatchery fish sampled was not significantly different than those containing fry (Table 2). Also, steelhead release lengths or condition factors do not appear to have influenced predation rates. Hatchery steelhead mean release length was 204 mm in 1996, 195 mm in 1997 and 198 mm in 1998. Condition factors of smolts averaged 0.94 in 1996, 1.02 in 1997, and 0.97 in 1998. Thus, length and condition factor in the high predation year (1998) was intermediate to low predation years. However, in 1998, the mean length of steelhead sampled while seining was significantly longer (11 mm) than

Table 1. Frequency (as percent) and mean of the number of salmonid fry in stomachs of hatchery coho salmon, steelhead, and sea-run cutthroat trout captured in 1995–1998 in the Lewis River, Washington.

		Number of fry in stomachs							Mean number	No. of
Species	Year	0	1	2	3	4	5	6	per stomach	stomachs
Coho	1997	96.7	2.0	0.9	0.3	0.1	0.0	0.0	0.05	1,209
salmon	1998	93.1	4.3	1.8	0.4	0.2	0.0	0.2	0.11	447
Steelhead	1995–1996	98.6	1.4	0.0	0.0	0.0	0.0	0.0	0.01	74
	1997	97.3	2.7	0.0	0.0	0.0	0.0	0.0	0.03	110
	1998	52.1	10.4	20.8	8.3	6.3	2.1	0.0	1.13	48
Cutthroat	1995–1996	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	4
trout	1997	0.0	100.0	0.0	0.0	0.0	0.0	0.0	1.00	1
	1998	13.3	20.0	20.0	40.0	0.0	6.7	0.0	2.13	15

Table 2. Mean fork length (range), in millimeters, of hatchery salmonid smolts sampled for stomach contents in 1995–1998 in the Lewis River, Washington.

Year	Coho salmon	Steelhead	Sea-run cutthroat trout
1995–1996			
All fish	NA	202(115–234)	219(194–230)
Fish with prey	--	NA	--
1997			
All fish	119(40–201)	195(138–236)	NA
Fish with prey	128(89–176)[a]	187(183–193)	--
1998			
All fish	141(74–215)	209(158–259)	231(205–279)
Fish with prey	136(105–177)	220(175–259)	233(205–279)

[a] Significantly different, t = 2.07, $P < 0.05$, df = 1,247

those released at the hatchery (t = 4.70, df = 846, $P < 0.01$), suggesting that some post-release growth occurred or that smaller smolts emigrated more rapidly and thus were not sampled as frequently.

The substantial increase in predation rates in 1998 probably reflects an increased chinook fry abundance that year. Nearly 3 times more chinook fry appeared to be present in 1998 compared to 1997, based on similar seining effort, timing and sampling sites. While the number of fry consumed per hatchery coho salmon and cutthroat trout doubled between 1997 and 1998, the increase for hatchery steelhead was about 38 fold. The reason for this large increase is not readily apparent. Most steelhead smolts were captured after May 27 in 1998, whereas most were caught before that date in 1997. As most hatchery steelhead emigrate by mid-May, possibly a higher rate of steelhead non-migration occurred in 1998 and those fish used chinook fry in their diet at a higher rate.

Because data were not available on evacuation rates of fry consumed, hatchery smolt residency time by species, the number of wild chinook salmon fry produced each year, or their vulnerability over time, total fry consumed by hatchery smolts was not estimated.

Although hatchery coho salmon smolts had considerably lower fry predation rates than steelhead, their potential consumption was much greater than steelhead because 10 times more coho salmon than steelhead are released. If the observed predation rates were applied to the hatchery releases for both species, coho salmon would have consumed nearly 3 times as many chinook salmon fry as steelhead.

The estimated mean number of chinook salmon fry consumed per hatchery smolt was much greater in the Lewis River than in upper Columbia River areas (Cannamela[4] 1993, Martin et al.[5] 1993, Jonasson[6] 1995), undoubtedly a reflection of chinook fry abundance. If Lewis River wild chinook salmon adult returns fall below escapement

goals, releasing hatchery smolts downstream of chinook rearing areas should be considered. This practice has been employed in recent years in eastern Washington where hatchery steelhead were previously released in endangered chinook salmon rearing areas. Another way to reduce predation would be to release hatchery smolts when most juvenile chinook salmon have grown large enough to avoid predation. Releases of hatchery sea-run cutthroat trout on the Lewis River will stop after the 1999 release, due to their consumption of wild chinook salmon fry as smolts and their low return rates as adults.

ACKNOWLEDGMENTS

We thank T. Pearsons, E. Lesko, G. Vander Haegen, and C. Sharpe for manuscript review. D. Pruett did the graphics. This study was funded by Pacificorp Corporation, Portland, Oregon.

LITERATURE CITED

Beauchamp, D.A. 1995. Riverine predation on sockeye salmon fry migrating to Lake Washington. North American Journal of Fisheries Management 15:358-365.

Trotter, P.C. 1997. Sea-run cutthroat trout: Life history profile. Pages 7-15 *in:* J.D. Hall, P.A. Bisson, and R.E. Gresswell, editors. Sea-run cutthroat trout: Biology, management, and future conservation. Oregon Chapter, American Fisheries Society, Corvallis, Oregon, USA.

Vander Haegen, G.E., J.M. Tipping, and S.A. Hammer. 1998. Consumption of juvenile salmonids by adult steelhead in the Cowlitz River, Washington. California Fish and Game 84:48-50.

Received: 17 December 1998
Accepted: 21 July 1999

California Fish and Game 85(3):130-134 1999

FIRST RECORD OF DEEPWATER BASS, *SERRANUS AEQUIDENS* (SERRANIDAE), FROM CALIFORNIA

DANIEL J. PONDELLA, II
Vantuna Research Group
Moore Laboratory of Zoology
Occidental College
Los Angeles, California 90041
e-mail: Pondella@oxy.edu

The marine seabasses (Serranidae:Serraninae) are circumglobal perciforms found primarily at tropical and subtropical latitudes with a few temperate representatives (Nelson 1994). In California, only 3 species are normally found: kelp bass, *Paralabrax clathratus*; barred sand bass, *P. nebulifer*; and spotted sand bass, *P. maculatofasciatus* (Eschmeyer et al. 1983). There is a single verbal account of golden spotted rock bass, *P. auroguttatus*, caught out of Redondo Beach (Miller and Lea 1972, Fitch and Schultz 1978). Unfortunately, there is no voucher for this specimen. The genus *Serranus*, with 3 known representatives in the Gulf of California and the Pacific coast of Baja California Sur and 7 in the eastern Pacific, has previously never been reported in California (Miller and Lea 1972; Thomson et al. 1979; Eschmeyer et al. 1983; Allen and Robertson 1992, 1994). The 3 Baja California species are deepwater bass, *Serranus aequidens*; barred serrano, *S. fasciatus*; and *S. huascarii*, for which a common name has not been reported (Thomson et al. 1979, Escobar-Fernández and Siri 1997).

While conducting a trawl survey aboard Occidental College's R/V *VANTUNA* on 23 April 1990, 2 adult deepwater bass (Fig. 1) were collected at Whites Point, Rancho Palos Verdes, California (33°42.00'N, 118°30.22'W). A standard 7.6-m headrope otter trawl was used and the fishes were captured at a depth of 77 m over a soft bottom. This depth is consistent with depths (73–260 m) previously reported for this species. R.H. Rosenblatt at the Scripps Institute of Oceanography (SIO) identified the deepwater bass and they were subsequently deposited in the SIO Marine Vertebrates Collection (SIO 90-79). This note documents the 1st collection of deepwater bass in California.

The type specimen of the deepwater bass, *Serranus aequidens* Gilbert, 1890 (USNM 44277) was collected in 1889 on the Albatross Expedition (Station 2996) in the southern Gulf of California, 24°30.15'N, 110°29.00'W (Gilbert 1890). *Serranus aequidens* has been referred to as serrano (Gamboa 1991) and as deepwater bass (Bussing and López 1993). Deepwater bass is more appropriate, as it is descriptive, anglicized, and more specific than serrano, which has been used generically for *Serranus* (Walford 1937, Thomson et al. 1979, Robins et al. 1991). The deepwater bass is dusky brown to gray in color, lighter below the lateral line. Seven vague dark blotches occur along the lateral line (Walford 1937). This drab color plus 5 oblique scale rows on the cheek (between the orbit and preopercle angle) easily separates deepwater bass from barred serrano (Walford 1937). Barred serranos also have

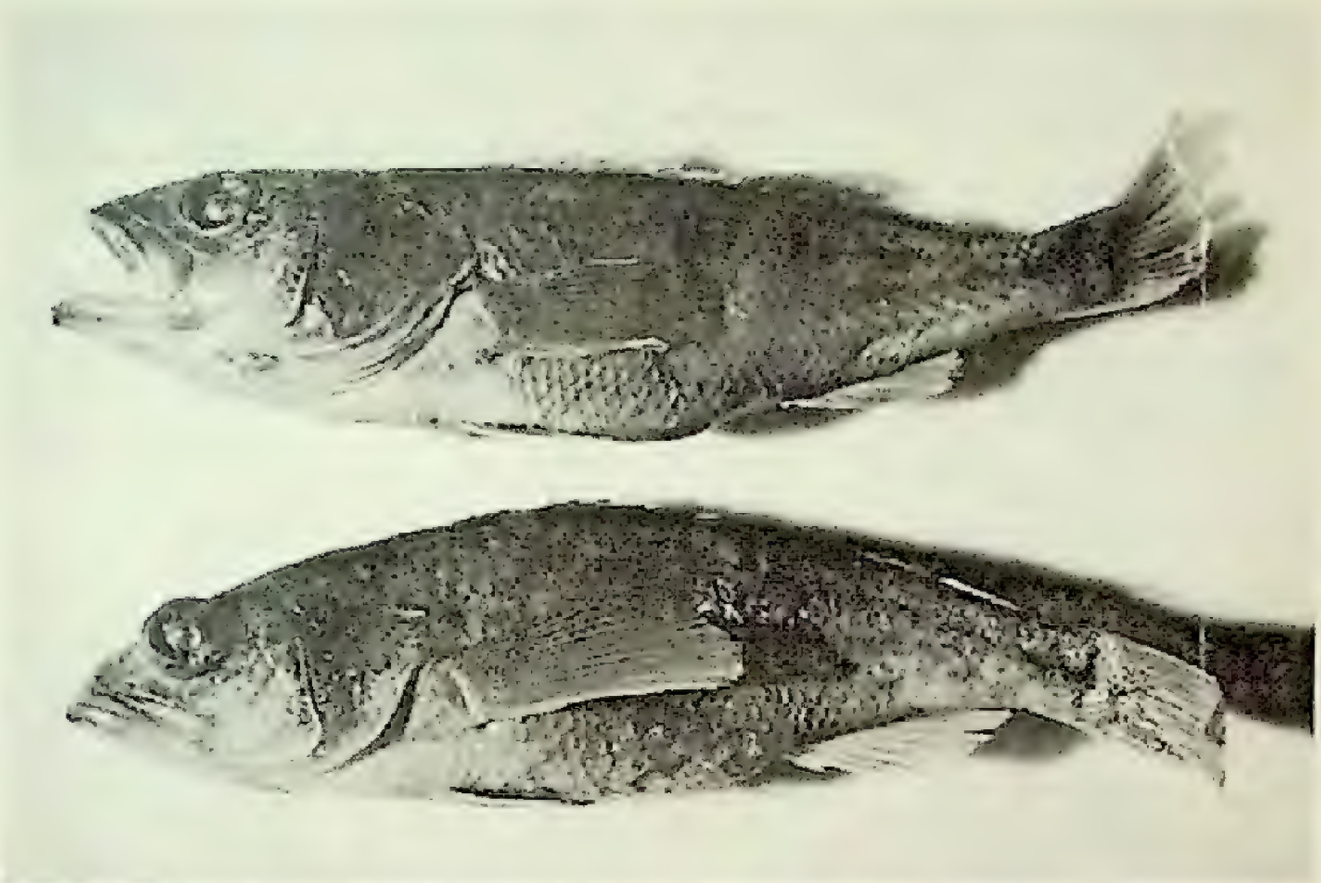


Figure 1. Left lateral view of 2 preserved deepwater bass, *Serranus aequidens*, (200.6 [top] and 200.3 mm SL [bottom]; SIO 90-79) captured at 77 m off Whites Point, Rancho Palos Verdes, California on 23 April 1990.

truncate caudal fins, whereas deepwater bass and *S. huascarii* have lunate caudal fins (Fischer et al. 1995). Fischer et al. (1995) also report 2 characters that can be used to differentiate *S. huascarii* from deepwater bass: gill rakers and the ratio of body depth to standard length. Gill rakers (including rudimentary) on the inferior primary gill arch are 10–12 for barred serrano, 12–13 for *S. huascarii*, and 16 for deepwater bass. These 2 specimens had 16 and 17 gill rakers. Counts and measurements are given in Table 1. The ratio of body depth to standard length is 4.0 in *S. huascarii* and 3.5–3.8 in deepwater bass. The ratios for these specimens are 3.7 and 3.6. Meisler[1] (1987) adds an additional character of a black bar on the posterior caudal fin margin of *S. huascarii*, which is not present on deepwater bass. Measurements, meristics, and color patterns of this collection are consistent with previous descriptions of this species.

The deepwater bass, a known food item of the California sea lion, *Zalophus californianus*, is generally abundant in the southern Gulf of California (Gamboa 1991) and is known to occur over soft bottom habitats (Thomson et al. 1979). It ranges south to Chile and Peru (Hildebrand 1946). C.L. Hubbs collected a single specimen (SIO 65-227) on 27 June 1965 by otter trawl 14.8 km southeast of Punta Tosca

[1] Meisler, M.R. 1987. Limits and relationships of serranine seabasses, with revisions of Serranus and Mentiperca (Pisces: Serranidae). Ph.D. Dissertation, University of Southern California, Los Angeles, California, USA.

Table 1. Meristic and morphometric data for 2 deepwater bass collected in California (SIO 90-79). Measurements are in millimeters.

Counts	Specimen 1	Specimen 2
Dorsal fin	X, 12	X, 12
Anal fin	III, 7	III, 7
Pectoral fin (l/r)	17/18	18/18
Gill rakers (l)	26	27
Inferior gill rakers (l)	16	17
Lateral line pores	52	49
Measurements (% standard length)		
Standard length	200.6	200.3
Total length	237.2	239.3
Head length	78.7 (39.2)	77.4 (38.6)
Snout length	21.1 (10.5)	19.6 (9.8)
Orbit width	16.0 (7.9)	17.2 (8.6)
Bony interorbital width	19.2 (9.6)	19.7 (9.8)
Suborbital height	5.3 (2.6)	4.9 (2.4)
Pectoral length	49.8[a] (24.8)	56.6 (28.3)
Pelvic length	22.2[a] (11.1)	37.0 (18.5)
Pelvic spine length	18.8 (9.4)	19.3 (9.6)
1st dorsal spine	7.8 (3.9)	7.9 (3.9)
2nd dorsal spine	12.2 (6.1)	12.6 (6.3)
3rd dorsal spine	13.5 (6.7)	23.9 (11.9)
4th dorsal spine	18.1[a] (9.0)	22.6 (11.3)
5th dorsal spine	20.2 (10.1)	23.9 (11.9)
1st anal spine	5.0 (2.5)	5.8 (2.9)
2nd anal spine	8.0 (4.0)	10.2 (5.1)
3rd anal spine	13.2 (6.6)	15.8 (7.9)
Body depth	54.1 (27.0)	55.2 (27.6)
Caudal peduncle depth	17.5 (8.7)	18.1 (9.0)
Dorsal length of caudal peduncle	23.2 (11.6)	24.0 (12.0)
Ventral length of caudal peduncle	32.1 (16.0)	33.8 (16.9)

[a] Fin damaged during collection

(24°11.00'N, 111°29.10'W), the southern tip of Isla Santa Margharita, Baja California Sur (H.J. Walker, SIO, personal communication). R.N. Lea (California Department of Fish and Game, personal communication) collected 2 specimens (LACM 30326.001) at Golden Gate Bank, Baja California Sur on 7 January 1969 approximately 111 km southwest of Bahia San Juanico (25°34.00'N, 113°27.00'W) and these specimens are still in good condition. These are the only known museum collections of deepwater bass on the Pacific coast of Baja California, making this collection a northern range extension of approximately 1000 km.

There has been much attention to the warming of our coastal waters over the last 2 decades (Hayward 1997) and associated shift in ichthyofaunas in the Southern California Bight (Stephens et al. 1984, Mearns 1988). Potentially expatriated species

(e.g., Lea and McAlary 1994, Pondella 1997, Pondella et al. 1998) have been reported in California from shallow subtidal habitats, including estuaries (Lea and Rosenblatt 1992). This collection suggests that this northward shift in species distributions is affecting deeper benthic species.

ACKNOWLEDGMENTS

I thank the Vantuna Research Group and the Department of Biology at Occidental College for support. J.M. Allen, R.N. Lea, and J.S. Stephens, Jr. were helpful in this research effort. I also appreciate the curatorial assistance of H.J. Walker, R. Feeney, and C. Klepadlo.

LITERATURE CITED

Allen, G.R. and D.R. Robertson. 1992. *Serranus socorrensis*, a new species of serranid fish from the tropical eastern Pacific Ocean. Revue Francaise D' Aquariologie, Herpetologie 19:37-40.

Allen, G.R. and D R. Robertson. 1994. Fishes of the tropical eastern Pacific. University of Hawaii Press, Honolulu, Hawaii, USA.

Robins, C.R. and 6 others. 1991. Common and scientific names of fishes from the United States and Canada, 5th edition. Special Publication 20. American Fisheries Society, Bethesda, Maryland, USA.

Bussing, W.A. and M.I. López. 1993. Demersal and pelagic inshore fishes of the Pacific coast of lower Central America. Revista Biología Tropical. Escuela de Biología y CIMAR, Universidad de Costa Rica, San José, Costa Rica.

Eschmeyer, W.N., E.S. Herald, and H. Hammann. 1983. A field guide to Pacific coast fishes of North America. The Peterson Field Guide Series. Houghton Mifflin Company, Boston, Massachusetts, USA.

Escobar-Fernández, R. and M. Siri. 1997. Vernacular and common names of fishes of the Mexican Pacific. Universidad Autónoma de Baja California and Sociedad Ictiológica Mexicana, A.C., México.

Fischer, W., F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. H. Niem. 1995. Guia FAO para la identificacion de especies para los fines de la pesca. Pacífico centro-oriental. Volumen III. Vertebrados. Parte 2. Organizacion de las Naciones Unidas para la Agricultura y la Alimentacion, Roma, Italia.

Fitch, J.D. and S.A. Schultz. 1978. Some rare and unusual occurrences of fishes off California and Baja California. California Fish and Game 64:74-92.

Gamboa, D.A. 1991. Otolith size versus weight and body-length relationships for eleven fish species of Baja California, Mexico. Fishery Bulletin 89:701-706.

Gilbert, C.H. 1890. A preliminary report on the fishes collected by the steamer Albatross on the Pacific coast of North America during the year 1889, with descriptions of twelve new genera and ninety-two new species. Proceedings of the U.S. National Museum 13:49-126.

Hayward, T.L. 1997. Pacific Ocean climate change: Atmospheric forcing, ocean circulation and ecosystem response. Trends in Ecology and Evolution 12:150-154.

Hildebrand, S.F. 1946. A descriptive catalog of the shore fishes of Peru. Bulletin of the United States National Museum 189.

Lea, R.N. and R.H. Rosenblatt. 1992. The Cortez grunt (*Haemulon flaviguttatum*) recorded from two embayments in southern California. California Fish and Game 78:163-165.

Mearns, A.J. 1988. The "odd fish": Unusual occurrences of marine life as indicators of changing ocean conditions. Pages 137-176 *in:* D.F. Soule and G.S. Kleppel, editors. Marine organisms as indicators. Springer-Verlag, New York, New York, USA.

Miller, D.J. and R.N. Lea. 1972. Guide to the coastal marine fishes of California. California Department of Fish and Game, Fish Bulletin 157.

Nelson, J.S. 1994. Fishes of the world, 3rd edition. John Wiley & Sons, New York, New York, USA.

Pondella, II, D.J. 1997. The first occurrence of the panamic sergeant major, *Abudefduf troschelii* (Pomacentridae), in California. California Fish and Game 83:84-86.

Pondella, II, D.J., R. Snodgrass, M. Craig, and H. Khim. 1998. Re-occurrence of the threebanded butterflyfish, *Chaetodon humeralis* (Chaetodontidae), with notes on its distribution in southern California. Bulletin of the Southern California Academy of Sciences 97:121-124

Stephens, J.S., Jr., P.A. Morris, K. Zerba, and M. Love. 1984. Factors affecting fish diversity on a temperate reef: The fish assemblage of Palos Verdes Point, 1974–1981. Environmental Biology of Fishes 11:259-275.

Thomson, D.A., L.T. Findley, and A.N. Kerstitch. 1979. Reef fishes of the Sea of Cortez. John Wiley & Sons, New York, New York, USA.

Walford, L.A. 1937. Marine game fishes of the Pacific coast from Alaska to the equator. University of California Press, Berkeley, California, USA.

Received: 21 January 1999
Accepted: 22 October 1999

California Fish and Game 85(3):135-138 1999

NORTHERN RANGE EXTENSION OF THE WHITE GRUNT, *HAEMULOPSIS LEUCISCUS*

JORGE A. ROSALES-CASIÁN
Grupo de Ecología Pesquera
Departamento de Ecología, División de Oceanología
Centro de Investigación Científica y de Educación Superior de Ensenada, B.C.
Km 107 Carretera Tijuana-Ensenada, A.P. 2732.
Ensenada, Baja California, México.
U.S. Mailing Address: P.O. Box 434844
San Diego, California 92143-4844
e-mail: jrosales@cicese.mx

GORGONIO RUIZ-CAMPOS
Laboratorio de Vertebrados, Facultad de Ciencias
Universidad Autónoma de Baja California, México
A. P. 1653
Ensenada, Baja California, México
U.S. Mailing Address: P.O. Box 189003-064
Coronado, California 92178

The white grunt, *Haemulopsis leuciscus* (Günther, 1864), also known as "burro blanco," is a common benthic species in tropical coastal waters from Bahia Magdalena, Baja California Sur, Mexico and the Gulf of California (De La Cruz-Agüero et al. 1994) to Peru (McKay and Schneider 1995, Amezcua-Linares 1996). This species has low fishery importance and is commonly found on sandy and muddy bottoms of coastal waters in the Mexican Pacific region (Yañez-Arancibia[1] 1977, Amezcua-Linares 1996). Adults frequently enter coastal lagoons and estuaries for feeding and protection (Castro-Aguirre 1978, Amezcua-Linares, 1996), consuming crustaceans, molluscs, and polychaetes (Yañez-Arancibia[1] 1977, Amezcua-Linares 1996).

On 30 March 1998, a 94-mm standard length juvenile white grunt was captured with a 7.5-m otter trawl in an eastern arm of the Bahia de San Quintin, Baja California, Mexico (30°27'8"N, 115°57'4"W). The juvenile was taken at a depth of 5 m on a muddy bottom characterized by fine slimes and dense eelgrass, *Zostera marina*. The white grunt was not reported in a list of the fish species found in Bahia de San Quintin from 1993 to 1995 (Rosales-Casián 1996).

The previously known northernmost distribution of the white grunt is Bahia Magdalena (Puerto Lopez Mateos) on the western coast of Baja California (De La Cruz-Agüero et al. 1994) and Bahia Concepcion in the Gulf of California (De La Cruz-Agüero 1997). The white grunt collected in Bahia de San Quintin extends

[1] Yañez-Arancibia, A. 1977. Taxonomía, ecología y estructura de las comunidades ictiofaunísticas en nueve lagunas costeras del estado de Guerrero (Pacífico Central de México). Ph.D. dissertation, Centro de Ciencias del Mar y Limnología, UNAM, México.

the range of the species 702 km farther north than previously reported in Bahía Magdalena.

The specimen was identified by the combination of the following characteristics (Jordan and Evermann 1896, McKay and Schneider 1995): body moderately elongate; deepest at shoulders; body depth and head length 3.0 and 3.2 times into the standard length; interorbital and preorbital width, 4.8 and 3.6 in head length; mouth small, lower jaw slightly included; preopercle sharply serrated; tip of the upper jaw hidden under the orbital bone; dorsal fin with 12 spines and 15 soft-rays and anal fin with 3 spines and 8 soft-rays; 1st gill arch with 6 and 13 rakers on upper and lower limb; 3rd anal spine, when depressed, reaching the base of last soft-ray; body grayish-silvery, clearer in the ventral region; a faint blotch on axil of pectoral fin. The specimen is deposited in the fish collection of the Facultad de Ciencias, Universidad Autónoma de Baja California, catalog number UABC-874.

The presence of this Panamanian fish as far north as Bahía de San Quintín is likely a result of the presence of a surface warm water mass resulting from an El Niño oceanographic phenomenon. The 1997–1998 El Niño event was characterized by rapid development, strength, and the new monthly record high for sea-surface temperatures in the eastern equatorial Pacific (McPhaden 1999).

ACKNOWLEDGMENTS

Funds for this research were provided by CICESE. We thank José De La Cruz-Agüero, Centro Interdisciplinario de Ciencias Marinas, Instituto Politécnico Nacional (CICIMAR-IPN), at La Paz, Baja California Sur, for verifying the identification of the white grunt.

LITERATURE CITED

Amezcua-Linares, F. 1996. Peces demersales de la plataforma continental del Pacífico central de México. Instituto de Ciencias del Mar y Limnología-UNAM and Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, México.

Castro-Aguirre, J.L. 1978. Catálogo sistemático de los peces marinos que penetran en las aguas continentales de México, con aspectos zoogeográficos y ecológicos. Instituto Nacional de Pesca, México. Serie Científica Número 19:1-298.

De la Cruz-Agüero, J., F. Galván Magaña, L. Abitia Cárdenas, J. Rodríguez-Romero, and F.J. Gutierrez-Sánchez. 1994. Lista sistemática de los peces marinos de Bahía Magdalena, Baja California Sur, México. Ciencias Marinas, 20:17-31.

De La Cruz-Agüero, J., M. Arellano-Martinez, V.M. Cota-Gómez, and G. De La Cruz-Agüero. 1997. Catálogo de los peces marinos de Baja California Sur. Centro Interdisciplinario de Ciencias Marinas-IPN and Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, México.

Gorsline, D.F. and R.L. Stewart. 1962. Benthic marine exploration of Bahía San Quintín, Baja California: Marine and quaternary geology. Pacific Naturalist 2:275-280.

Jordan, D.S. and B.W. Evermann. 1896. The fishes of North and Middle America. Bulletin of the United States National Museum 47.

McKay, R.J. and M. Schneider. 1995. Haemulidae. Pages 1136-1173 *in:* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K.E. Carpenter, and V.H. Niem, editors. Guía FAO para la identificación de especies para los fines de la pesca. Pacífico Oriental. Volume II. Vertebrados. Part 1. Rome, Italy.

McPhaden, M.J. 1999. The child prodigy of 1997-98. Nature 398:559-562.

Rosales-Casián, J.A. 1996. Ichthyofauna of Bahía de San Quintín, Baja California, México, and its adjacent coast. Ciencias Marinas 22:443-458.

Received: 30 March 1999
Accepted: 6 August 1999

California Fish and Game 85(3):138-139 1999

AN ANIMAL TRACK CASTING METHOD USING DOLOMITE, SAND, AND SPRAY ADHESIVE

HOWARD O. CLARK, JR.
Endangered Species Recovery Program
1900 Gateway Boulevard, #101
Fresno, California 93727
e-mail hclark@elite.net

Recording and preserving tracks are good ways to document the presence of species. Various methods have been developed to measure tracks, but plaster casting is the most common (e.g., Aiken 1930). Other methods include paraffin wax, natural mud molds (Murie 1954), wood putty, spray insulation foam (Halfpenny 1986), and rosin-paraffin (Kent et al. 1985). Success with paraffin has been limited (Kent et al. 1985) and plaster casts are fragile and bulky to store (Halfpenny 1986).

Carbon-sooted aluminum track plates are the most widely used method of track preservation. Transparent tape is used to lift and preserve tracks off aluminum plates (Orloff et al. 1993). Animal tracks left on carbon-sooted aluminum track plates are highly detailed and identifying the species is much easier than traditional casting methods (Taylor and Raphael 1988, Orloff et al. 1993, Zielinski and Truex 1995). However, carbon-sooted aluminum track plates are bulky and inconvenient to prepare for use, even if the aluminum plates are chalked instead of sooted. Moreover, research locations near urban settings or busy roadways are subject to vandalism or non-malicious tampering. Because of this, aluminum track plates are not always suitable for these areas.

To evaluate an alternative to these methods of documenting tracks, I placed a tray, measuring 122 cm x 45 cm x 5 cm, in an open area and filled it with a 50/50 mixture of dolomite and fine-grained sand. I smoothed the track-medium surface using a hand-held cement float. Domestic cats were allowed to walk across the medium, leaving behind a variety of tracks. The tracks were then frozen in place to prevent distortion by spraying them with fast-drying polyurethane. I sprayed from a distance of 30 cm, moving the spray can back and forth, not allowing the spray to soak the track. Once the polyurethane dried, I sprayed 3M (Minnesota Mining and Manufacturing Co.[1], St. Paul, Minnesota, USA) spray adhesive on the tracks. I initially moved the spray adhesive can from side to side, spraying in short bursts until a thin film completely covered the tracks. Once the film formed, spraying was not likely to distort the tracks, and I continually sprayed until the track concavities were filled with adhesive.

I also made plaster casts (Smith 1982) in the dolomite/sand mixture as a comparison casting method. I collected 30 spray adhesive casts and compared them to 30 plaster casts made under the same conditions. Both methods exhibited good 3-dimensional detail, emphasizing track form and size. Plaster casts could be lifted within an hour, but the spray adhesive casts could not be lifted for 3–4 hours in hot weather (~38°C). At 4 hours, the spray adhesive tracks were still soft and could be

[1] Use of trade names does not imply endorsement by the California Department of Fish and Game.

distorted with excessive handling. A 12-hour curing time was required to ensure a firm cast. In both methods, sand particles attaching to the casts degraded the quality of details.

Three advantages of spray adhesive casts over plaster casts were evident: 1) less storage space, 2) a reduced carrying load for field casting, and 3) less time spent preparing and making casts. Spray adhesive casts are relatively flat (no thicker than 5 mm for cat tracks) and fit nicely in an envelope. Alternatively, plaster casts are comparatively thick (average thickness 15 mm for cat tracks), require more storage space, and are fragile. Casting materials in the field for the spray adhesive method amounted to 2 spray cans, 1 polyurethane and 1 spray adhesive. Plaster casting requires carrying a container of plaster powder, a mixing can, a container of water, and a mixing stick. Additionally, clean-up is time consuming. The spray adhesive method only takes about a minute to execute, while the plaster method can take up to several minutes.

Casts made by both methods are comparable in detail, but plaster appears to show markedly more detail because fewer sand particles adhered to the plaster. Sand particles readily adhered to the cast surface using the spray adhesive method. The sand particles, however, did not distort the track, and the track was clearly visible.

Although carbon-sooted aluminum tracking stations are a widely accepted method, they cannot be used under all circumstances. Depending on the research objective and local factors, other tracking methods may be better suited. The dolomite, sand, and spray adhesive method, a variation on the casting theme, is one solution.

ACKNOWLEDGMENTS

I thank D. Williams and G. Warrick for reviewing the manuscript; S. Clifton and C. Johnson for their comments; and H. Clark, Sr. for his mineral geology expertise. The California Department of Transportation funded a portion of this work.

LITERATURE CITED

Aiken, R. 1930. Tracks: A unique method of collecting them. Nature Magazine 15:170.

Halfpenny, J. 1986. A field guide to mammal tracking in North America, second edition. Johnson Publishing Co., Boulder, Colorado, USA.

Kent, D.M., M.P. Harris, G.L. Abegg, and T.H. Kunz. 1985. A new moulage technique for casting animal tracks. The American Biology Teacher 47:432-433.

Murie, O.J. 1954. A field guide to animal tracks, second edition. Houghton Mifflin Co., New York, New York, USA.

Orloff, S.G., A.W. Flannery, and K.C. Belt. 1993. Identification of San Joaquin kit fox (*Vulpes macrotis mutica*) tracks on aluminum tracking plates. California Fish and Game 79:45-53.

Smith, R.P. 1982. Animal tracks and signs of North America. Stackpole Books, Harrisburg, Pennsylvania, USA.

Taylor, C.A. and M.G. Raphael. 1988. Identification of mammal tracks from sooted track stations in the Pacific Northwest. California Fish and Game 74:4-15.

Zielinski, W.J. and R.L. Truex. 1995. Distinguishing tracks of marten and fisher at track-plate stations. Journal of Wildlife Management 59:571-579.

Received: 21 April 1999
Accepted: 18 August 1999

California Fish and Game 85(3):140-143 1999

USE OF BURIED AND NON-BURIED TRAPS TO SAMPLE DESERT RODENTS

CHRISTOPHER S. FITZGERALD
Warnell School of Forest Resources
University of Georgia
Athens, Georgia 30602

PAUL R. KRAUSMAN
School of Renewable Natural Resources
The University of Arizona
Tucson, Arizona 85721
e-mail: krausman@ag.Arizona.EDU

MICHAEL L. MORRISON
Department of Biological Sciences
California State University
Sacramento, California 95819

Procedures for live-trapping small mammals in extreme climates should incorporate strategies for reducing trap fatalities if reliable estimates of abundance, survival, reproductive potential, and microhabitat use and selection are to be obtained. Additionally, trapping procedures should account for behavioral adaptations to existence in extreme conditions. In desert regions, the majority of small mammal species are nocturnal and typically are sampled at night with traps closed during daylight hours (Rosenzweig and Winakur 1969, Price 1978, Brown and Zeng 1989, Bowers and Brown 1992, Swann et al. 1997), but some studies of desert rodents incorporated day and night trap checks (Simons 1991, Kerley 1992, Andersen 1994).

Diel temperature fluctuations may be large in desert environments and captured animals may be vulnerable to hypothermia overnight and heat stress during day. Simons (1991) checked traps both day and night during rainstorms or cold periods to minimize trap fatalities. Others have used stuffing fiber or wool as bedding and insulation (Kerley 1992). Cotton absorbs moisture and will not provide insulation when wet. We found polyester fiber unsuitable for trap insulation because kangaroo rats, *Dipodomys* spp., frequently became entangled and had circulation cut off in their hind limbs. Some researchers used 2 trap checks at night to reduce overnight fatalities (Schroder and Rosenzweig 1975, Wondolleck 1978, Price and Waser 1985). Brown (1989) checked traps 2 or 3 times during the day and Andersen (1994) shaded traps with aluminum tents to prevent overheating. Night trap checks and shading devices add labor and costs to trapping studies.

Swann et al. (1997) used soil and litter to shade traps from sun exposure and provide some insulation from overnight cold (M.L. Morrison, personal communication), though the burying process was not described in that report. Using soil to insulate traps eliminates the added expense of purchasing manufactured trap tents or materials to construct shades and may provide an effective means of protecting

captured animals from overnight cold and morning heat prior to release. We used partially buried traps in a brush control study in southeastern Arizona to test their effectiveness compared to traps that were not buried. We predicted that fewer small species would be captured in buried traps due to reduced trap sensitivity caused by soil entering traps and interfering with the release mechanism.

We trapped 4 locations in the San Bernardino Valley, Cochise County, Arizona. Sites varied in vegetation and soil type and, therefore, in rodent species composition and abundance. All sites were within historic desert grassland or desert scrub communities, and varied from mesquite-tobosa (*Prosopis velutina-Hilaria mutica*) grassland to creosotebush-acacia (*Larrea tridentata-Acacia constricta*) associations.

We used a 7 x 7 trap configuration with 15-m spacing between trap stations. We placed 2 folding Sherman live traps (7.5 x 8.7 x 22.5 cm) at each station (98 traps per grid). One trap was partially buried with the door left exposed and the other trap was placed on the ground within 1 m of the buried trap. To bury a trap we dug a shallow trough with a pick and placed the trap horizontally or slightly inclined in the depression. The soil removed from the depression was used to cover the trap, leaving the trap door open and free of soil (Fig. 1). We baited traps with commercially available mixed birdseed because most rodents in the area are predominately granivorous. No insulation was used. We set traps within 2 hours of sunset and checked all traps within 2 hours of sunrise. For each animal captured, we recorded species, age class, sex, reproductive condition, body mass, trap station, and trap position (i.e., buried, non-buried). Each grid was trapped for 3 consecutive nights. Use and handling of rodents complied with the American Society of Mammalogists (1987) guidelines and the Animal Welfare Act enforced by the Institutional Animal Care and Use Committee, The University of Arizona, Tucson (Protocol Number 96-090).

We compared mean number of captures per location between buried and non-buried traps with a paired t-test. We also compared captures between buried and non-buried traps for animals weighing ≤15 g, ≤20 g, and >20 g. Originally, we chose 20 g as an upper limit for small-bodied captures because it excluded the larger species (kangaroo rats: Bailey pocket mouse, *Chaetodipus baileyi*; grasshopper mice, *Onychomys* spp.; cotton rats, *Sigmodon* spp.; and whitethroat woodrat, *Neotoma albigula*) and

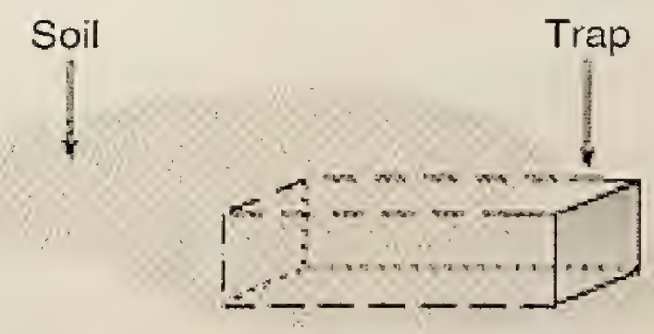


Figure 1. Buried traps were placed in a shallow trough and covered with the dirt removed from the trough. The trap door was open and free of soil.

incorporated juveniles and smaller species (white-footed mice, *Peromyscus* spp.; desert pocket mouse, *Chaetodipus penicillatus*; pygmy mouse, *Baiomys taylori*; and harvest mice, *Reithrodontomys* spp.). However, because a substantial number of captures weighed ≤15 g (including 3 species always <15 g), we decided to also use that mass as an upper limit for comparisons. We set $\alpha = 0.10$ for all tests.

We captured 218 rodents (including recaptures), 87 in buried traps and 131 in non-buried traps, in 1,176 trap-nights. The mean number of captures per site was significantly greater for non-buried traps (32.75 ± 5.53 SE) than for buried traps (21.75 ± 1.44 SE) ($t = 2.56$, $df = 3$, $P = 0.08$). However, within size groups, mean catches in buried and non-buried traps did not differ significantly (all $P > 0.10$) (Table 1).

Condition of trapped mammals varied between trap positions and among sites. Fifteen rodents in non-buried traps were torpid compared to none in buried traps. Most of the torpid rodents in non-buried traps (13) were found at 1 site.

The greater overall capture success for non-buried traps compared to buried traps may be attributed to reduced trap sensitivity or, alternatively, to soil disturbance at the trap stations. Perhaps the disturbed soil deterred rodents from entering buried traps by altering the microhabitat (e.g., disruption of scents, topography) or was perceived as predator digging activity. Although we did not find significant differences in the number of captures between buried and non-buried traps when stratified by rodent size, the difference between capture rates in buried and non-buried traps was greater for small-bodied rodents than for larger animals. This is consistent with our expectation that reduced sensitivity of the trap release mechanism due to the burying process may inhibit capture of the small-bodied rodents.

Burying traps may be a cost-effective means of reducing trap fatalities associated with temperature fluctuations in desert environments. However, burying traps adds labor when establishing grids or transects, setting traps, and processing captured animals. Additionally, folding live-traps may lose some sensitivity when partially buried. This loss of sensitivity may decrease the representation of small-bodied species within the community and should be accounted for if accurate estimates of rodent abundance are to be achieved.

ACKNOWLEDGMENTS

Our study was funded by the U.S. Forest Service Rocky Mountain Experiment Station and the International Arid Lands Consortium. Technical support was provided

Table 1. Comparison of mean catch per sampling location of small mammals, by size group, in buried and non-buried live traps in the San Bernardino Valley, Arizona. Values in parentheses are standard errors.

Size group	Buried	Non-buried	t	df	P
All	21.75 (1.44)	32.75 (5.53)	2.56	3	0.08
≤15 g	3.00 (1.35)	6.75 (4.17)	1.32	3	0.28
≤20 g	5.50 (0.96)	11.25 (3.70)	1.74	3	0.18
>20 g	16.25 (2.10)	21.50 (6.51)	1.02	3	0.38

by C. Edminster, G. Gottfried, and L. DeBano. Field assistance was provided by S. Meagher. M. Price, T. Paulek, and V. Bleich reviewed the manuscript.

LITERATURE CITED

American Society of Mammalogists. 1987. Acceptable field methods in mammalogy: Preliminary guidelines approved by the American Society of Mammalogists. Journal of Mammalogy 68 (Supplement 4):1-18.

Andersen, D.C. 1994. Demographics of small mammals using anthropogenic desert riparian habitat in Arizona. Journal of Wildlife Management 58:445-454.

Bowers, M.A. and J.H. Brown. 1992. Structure in a desert rodent community: Use of space around *Dipodomys spectabilis* mounds. Oecologia 92:242-249.

Brown, J.S. 1989. Desert rodent community structure: A test of four mechanisms of coexistence. Ecological Monographs 59:1-20.

Brown, J.H. and Z. Zeng. 1989. Comparative population ecology of eleven species of rodents in the Chihuahuan Desert. Ecology 70:1507-1525.

Kerley, G.I.H. 1992. Ecological correlates of small mammal community structure in the semi-arid Karoo, South Africa. Journal of the Zoological Society of London 227:17-27.

Price, M.V. 1978. The role of microhabitat in structuring desert rodent communities. Ecology 59:910-921.

Price, M.V. and N.M. Waser. 1985. Microhabitat use by heteromyid rodents: Effects of artificial seed patches. Ecology 66:211-219.

Rosenzweig, M.L. and J. Winakur. 1969. Population ecology of desert rodent communities: Habitats and environmental complexity. Ecology 50:558-572.

Schroder, G.D. and M.L. Rosenzweig. 1975. Perturbation analysis of competition and overlap in habitat utilization between *Dipodomys ordii* and *Dipodomys merriami*. Oecologia 19:9-28.

Simons, L.H. 1991. Rodent dynamics in relation to fire in the Sonoran Desert. Journal of Mammalogy 72:518-524.

Swann, D.E., A.J. Kuenzi, M.L. Morrison, and S. DeStefano. 1997. Effects of sampling blood on survival of small mammals. Journal of Mammalogy 78:909-913.

Wondolleck, J.T. 1978. Forage-area separation and overlap in heteromyid rodents. Journal of Mammalogy 59:510-518.

Received: 9 November 1998
Accepted: 7 April 1999

California Fish and Game 85(3):144-145 1999

BOOK REVIEW

AVIAN CONSERVATION. RESEARCH AND MANAGEMENT. Edited by John M. Marzluff and Rex Sallabanks. 1998. Island Press, Washington, D.C. ix + 563 pages. $55.00, hard cover.

Conservation biology addresses the problems of managing rare and threatened populations. New subject areas in conservation biology, such as habitat degradation, minimal habitat requirements, critical population sizes, wildlife corridors, and techniques for monitoring and conserving limited populations, are being studied and used in adaptive management programs. Editors John M. Marzluff and Rex Sallabanks have assembled 31 chapters, by 58 authors, on the subject of *Avian Conservation. Research and Management*. Approximately half of the chapters were presented at the 1996 joint meeting of the American Ornithologists Union and the Raptor Research Foundation. The chapters are grouped into 7 parts. I will briefly comment on 1 or 2 chapters from each part.

Part I: Introduction. The Current Status of Avian Conservation Biology and Prescriptions for the Future. J.M. Marzluff and R. Sallabanks in "Past Approaches and Future Directions for Avian Conservation Biology" review a sample of 218 recent (1990–1996) articles from 9 major journals to determine trends in avian conservation research. In an examination of the time scale of avian research, they found that 73% of studies lasted < 3 years and only 5% lasted a decade or more.

Part II: Techniques for Conserving and Monitoring Birds. This part contains summary articles on recent work in genetics, spatial modeling, and geographic information systems, to name a few. R.C. Fleischer in "Genetics and Avian Conservation" remarks on the controversies in conservation genetics and addresses such subjects as how biologists perceive patterns and levels of genetic variation. Fleischer also comprehensively discusses methods and applications in avian conservation genetics.

Part III: Approaches for Conserving Endangered and Sensitive Species. S.R. Derrickson, S.R. Beissinger, and N.F.R. Snyder note in "Directions in Endangered Species Research" that researchers and managers are replacing the former reactive approach of studying single at-risk species with proactive programs to maintain habitat diversity and thereby preserve and protect ecosystem processes. In "The Role of Sensitive Species in Avian Conservation" J.R. Squires, G.D. Hayward, and J.F. Gore remind us that management plans that do not include charismatic species will generally be viewed unfavorably by the public, whereas plans that focus on high-profile species have a greater chance to influence public attitudes.

Part IV: Conservation in Forested Landscapes. J.R. Walters in "The Ecological Basis of Avian Sensitivity to Habitat Fragmentation" and L.L. Irwin in "Abiotic Influences on Bird-Habitat Relationships" agree that, although habitat fragmentation negatively influences bird populations, researchers still lack a general understanding of the factors that govern habitat selection for many birds. Walters believes that a

theory is required to explain fragmentation in terms of changed landscape structure and its interaction with varying bird species. Irwin thinks that bird-habitat models may be improved by adding indices of landscape structure.

Part V: Conservation in Nonforested and Urban Landscapes. In "Urban Environments: Influences on Avifauna and Challenges for the Avian Conservationist," J.M. Marzluff, F.R. Gehlbach, and D.A. Manuwal state that despite the obvious effects of urbanization on birds, researchers are still more inclined to conduct their research in wildland areas than in urban ones. Information is lacking for both native and exotic birds associated with the urban-wildland interface. Preliminary studies have shown that native birds nesting in urban areas serve as either sources or sinks for the adjacent rural landscape. Other urban-wildland mechanisms are at work; for example, increased reliance on bird feeders can interrupt wildland seed dispersal and pollination beyond the urban area.

Part VI: Global Variation in Conservation Needs. Three of the 7 chapters, by local researchers, discuss national avian conservation efforts in Israel, Russia, and Australia. National political and socioeconomic influences affect avian populations. For example, in "Research Priorities for Bird Conservation in Russia" V.M. Galushin and V.A. Zubakin note that the economic disaster in post-USSR Russia is having a positive affect on bird populations because millions of hectares of agricultural lands are being neglected, forest clearings are being overgrown, and environmental pollution has sharply decreased. The authors comment that, ironically, Russia has little financial incentive to monitor this natural experiment.

Part VII: Relevance of Conservation Research to Land Managers. L.S. Young and D.E. Varland in "Making Research Meaningful to the Manager" provide 18 succinct principles to help researchers develop meaningful research for management needs. For example, researchers often publish results in scientific journals, but managers also need researchers to integrate adaptive management reports into their final product. Several of the other chapters here are redundant as they reiterate similar principles or directly reference the Young and Varland rules.

This well-edited book provides strong insight into current thought in avian conservation research and management. Its value as a reference is augmented by a 88-page literature cited section and a contributing authors section that lists the professional addresses of the contributors. The conservation approaches described here should be of interest not only to ornithologists but to all workers involved in the management of natural resources.

– Liam H. Davis
California Department of Fish and Game
P.O. Box 47
Yountville, California 94599

California Fish and Game 85(3):146 1999

IN MEMORIAM

PATRICIA POWELL (1909–1999)

Patricia Powell passed away on 15 July 1999 at the age of 89 in Laguna Niguel, California. Pat was an outstanding librarian who retired from the Department of Fish and Game (CDFG) in November 1976 as supervisor of the Marine Technical Information Center (MTIC). Her work with the CDFG began in the late 1940s at the California State Fisheries Laboratory on Terminal Island, San Pedro, California, after service in the United States Marine Corps during World War II. As the CDFG's first librarian, she began the task of transforming a reading room for various state, federal, and international fisheries publications collected by CDFG marine scientists during the previous 3 decades into an invaluable resource that could shared with all. Under her astounding leadership, the MTIC grew to become one of the finest sources of marine science literature anywhere. She continued and expanded the CDFG tradition of exchanging fishery literature with other nations' fisheries laboratories and became well known in the fisheries world. She took a temporary assignment during the 1960s with the United Nations Food and Agriculture Organization to help set up a fisheries library in Uganda. Although she was recruited by other organizations, Pat chose to remain with the CDFG for the rest of her career. She even returned from retirement for a brief time in 1989 to advise and supervise the "down-sizing" of the MTIC, a regrettable undertaking for her and many others.

Patricia Powell was more than just "the librarian" roaming the stacks of books and periodicals. She took a keen interest in the people with whom she worked. Her carefully considered advice was instrumental in the publication process of the marine group. She was clearly a motivating factor for young biologists. Because of her mentoring, they became better prepared for their careers and their subsequent publications in the profession were much more significant. Pat's interest in helping others was not limited to marine biologists. Department of Fish and Game wardens, inland fishery biologists, and wildlife biologists, as well as students, professors, wildlife writers and reporters, and fishing industry representatives were all regular visitors to the MTIC. If they could not visit the library, Pat made sure that they got the help they needed, often through inter-library loans. This kept her active in the Special Library Association and other professional organizations.

Pat was truly a special person. She was an avid bird watcher and her sometimes shrill voice (especially when defending the library budget) and piercing blue eyes earned her the affectionate nickname "the blue-eyed shriek." She was a wonderful friend of many, an outstanding professional, and a delightful communicator with all those who had the good fortune to ask for her help.

Pat is survived by her son Michael.

–Tom Jow, John Baxter, and Rick Klingbeil
Marine Region
California Department of Fish and Game

INSTRUCTIONS FOR AUTHORS

MANUSCRIPTS: Refer to the CBE Style Manual (5th Edition) and a recent issue of *California Fish and Game* for general guidance in preparing manuscripts. Specific guidelines are available from the Co-Editors-in-Chief.

COPY: Use good quality 215 x 280-mm paper. Double-space throughout with 25-mm margins. Do not hyphenate at the right margin or right-justify text. Authors should submit four good copies of their manuscript, including tables and figures, to the Co-Editors-in-Chief. An electronic copy of the manuscript on diskette in word processor format will be required with the final accepted version.

CITATIONS: All citations should follow the name-and-year system. See a recent issue of *California Fish and Game* for the format of citations and Literature Cited. Completely spell out publication and periodical names in Literature Cited. Minimize references to unpublished ("gray") literature. Gray literature citations should be in footnotes.

ABSTRACTS: Every article, except notes, must be introduced by an abstract. Abstracts should be about one typed line per typed page of text. In one paragraph describe the problem studied, most important findings, and implications of the results.

TABLES: Start each table on a separate page and double-space throughout. Do not use vertical rules. Use tabs, not the spacebar, to space between columns. Footnotes in tables should be consecutive lower-case letters, with the sequence beginning again in each table.

FIGURES: Consider proportions of figures in relation to the usable page size of *California Fish and Game* (117 x 186 mm). Figures, including captions, cannot exceed this size. Figures and line-drawings should be clear, with well-defined lines and lettering. Lettering style should be the same throughout and large enough to be readable when reduced to finished size. Type figure captions on a separate page. High-quality photographs with strong contrast are acceptable and should be submitted on glossy paper. On the back and top of each figure or photograph, lightly write the figure number and senior author's last name. Be prepared to provide high-quality, scannable, original figures or graphics files on diskette with the final accepted manuscript.

PAGE CHARGES AND REPRINTS: Authors will be charged $40 per printed page and will be billed at publication of the manuscript. Explicit acceptance of page charges should be included in the submittal letter. Authors will receive a reprint order form along with the galley proof.

Editor, ***CALIFORNIA FISH AND GAME***
California Department of Fish and Game
4001 North Wilson Way
Stockton, CA 95205-2486

BULK RATE
U.S. POSTAGE
PAID
Sacramento, CA.
Permit No. 949